Special Publication SJ92-SP5

TIME DOMAIN ELECTROMAGNETIC MEASUREMENTS
EAST-CENTRAL FLORIDA

Performed For:

Governing Board of the
St. Johns River Water Management District
P.O. Box 1429
Palatka, Florida 32178-1429

(Contract No. 91G143)

Prepared By:

Blackhawk Geosciences, Inc.
17301 West Colfax Avenue, Suite 170
Golden, CO 80401

(BGI Project #91034)

December 16, 1991

December 16, 1991

This is to certify that I, Jim Hild, have reviewed the figures, tables, and text of the following report, and have retained one copy for my files.

By: James Hild

James Hild
Professional Geologist
State of Florida
Registration #PG-0001282

SEAL

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EXECUTIVE SUMMARY

Time domain electromagnetic (TDEM) measurements were made in the St. Johns River Water Management District (SJRWMD) in east-central Florida during August 1991. TDEM is a geophysical method that measures from the surface the resistivity layering (geoelectric section) of the subsurface. The objective of the TDEM survey was to infer from the geoelectric sections measured information about water quality in the Upper Floridan Aquifer, such as the first depth of occurrence of ground water with a chloride concentration greater than 1,000 mg/l, and the depth of the 250 mg/l isochlor.

The objective of determining the first depth of occurrence of ground water with a chloride concentration greater than 1,000 mg/l was most readily accomplished. At the 14 sites surveyed that depth varied between the 14 sites from about 180 ft below surface to in excess of 2,000 ft below surface. TDEM measurements are an indirect method for determining water quality, and validity of interpretations are best tested against salinity measurements in wells. At one site (Astronaut High School) a well penetrated the interface with highly saline water, and excellent agreement between depth to ground water of high salinity inferred from TDEM measurements and observed in the well, was obtained.

Determining water quality above the interface with ground water of high salinity, in particular determining the depth of the 250 mg/l isochlor is a more difficult objective to reliably accomplish. This objective is more sensitive to assumptions that necessarily need to be made about chemical composition of ground water and porosity. Also, in present day methods of analysis, surface geophysics resolve distinct boundaries. In real aquifers ground water quality generally changes gradually. Nevertheless, at the majority of sites meaningful information about water quality in the Upper Floridan aquifer was obtained that correspond with available regional data.

The impetus for using surface geophysics for obtaining water quality is its low cost per station compared to drilling, so that higher station density can be afforded. Surface TDEM measurements can, however, not deliver information about water quality to the same level of detail (e.g., chemical composition) or accuracy as can be derived from wells.

1.0 INTRODUCTION

This report covers the data acquisition, processing, interpretation, and results of a time domain electromagnetic (TDEM) measurements performed at 14 sites in the St. Johns River Water Management District (SJRWMD) in east-central Florida. TDEM is a geophysical method that determines from the surface the geoelectric section (resistivity layering) in the subsurface. From the geoelectric section in-turn information about geology and water quality can be inferred, because the electrical resistivity of the Earth depends on lithology, porosity, and concentration of dissolved solids in ground water.

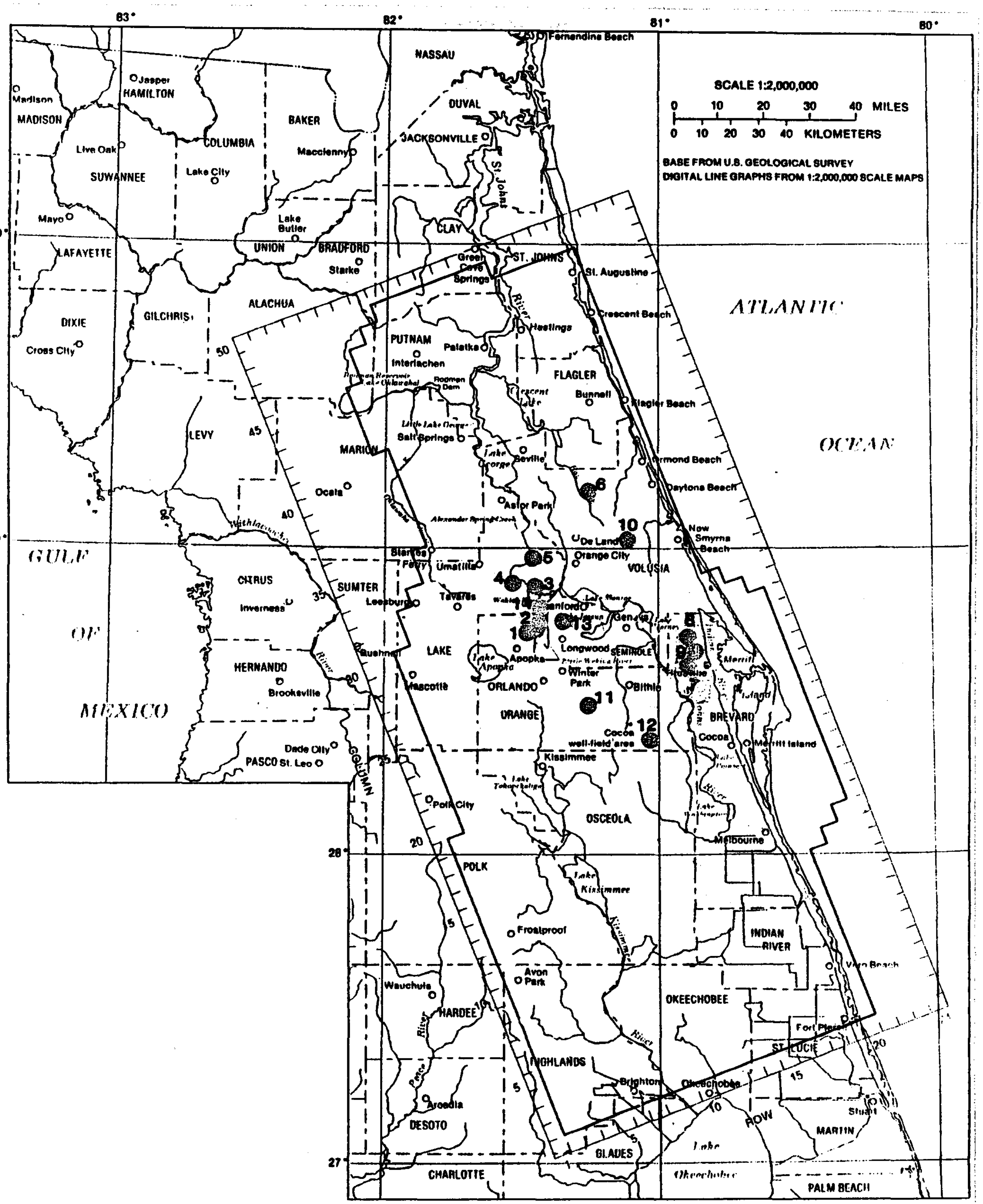
The objectives of the measurements at the 14 sites were to determine

- the interface between fresh water and highly saline water, defined here as ground water with a chloride concentration greater than 1000 mg/l
- the water quality in the Upper Floridan aquifer above the interface with highly saline water. Estimating the depth to the 250 mg/l isochlor particularly was an important objective.

The selection of the locations of the 14 sites for TDEM measurements were made by personnel of SJRWMD, and the overview map of Figure 1-1 shows their location.

The hydrogeologic setting of the 14 sites is expected to be similar. All sites are over the Floridan aquifer system, a system defined (Miller, 1990)on the basis of permeability. In general, the system is at least 10 times more permeable than its bounding upper and lower confining units. The aquifer system is thick and widespread, and the rocks within it generally vary in permeability. It is divided into an Upper Floridan aquifer and a Lower Floridan aquifer, separated by a less permeable unit in most places, and bounded above and below by confining units that may be less permeable.

Figure 1-2 is a stratigraphic column typical of the area, and it also summarizes characteristics of the various units. The geologic formations that comprise the Floridan aquifer system are all carbonate rocks, and most of them are of Eocene age. In places, however, rocks as young as Miocene age are included in the system. The Hawthorn Group and younger primarily clastic material overlies the carbonate rocks at most sites in the SJRWMD. The thicknesses and properties of these units are highly variable. Their composition may vary from permeable sands to impermeable clayey quartz.




TDEM Sounding Site

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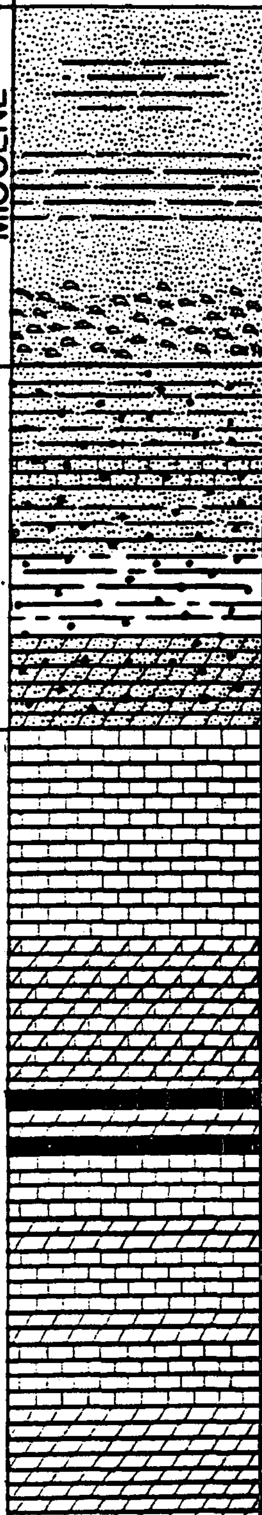
SITE LOCATION MAP

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

PROJECT NO: 91094 **Figure 1-1**

TYPICAL HYDROSTRATIGRAPHIC COLUMN IN WEKIVA RIVER AREA



AGE	FORMATION	AQUIFER	THICKNESS	DESCRIPTION
LATE AND POST MIOCENE	SURFICIAL MATERIAL	SURFICIAL AQUIFER	34 ft. to 139 ft.	Sand, Clay, and Coquina
MIOCENE	HAWTHORN GROUP	INTERMEDIATE AQUIFER AND CONFINING UNIT	25 ft. to 150 ft.	Sand, Clay, Limestone, and Dolostone, mostly phosphatic
			3 ft. to 32 ft.	Basal Hawthorn: Dolostone, sandy, phosphatic, hard
EOCENE	OCALA LIMESTONE	FLORIDAN AQUIFER	20 ft. to 112 ft.	Limestone, relatively pure Coquina, bio- and foraminiferal
			9 ft. to 57 ft.	Lower Ocala: Limestone, dolomitic, coquinoid
	AVON PARK LIMESTONE		150 ft. to 330 ft.	Limestone and Dolostone with Peat (disseminated and as beds) or Clay beds
				Avon Park: Dolostone, very hard, low porosity zone

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TYPICAL HYDROSTRATIGRAPHIC COLUMN IN WEKIVA RIVER AREA

St. Johns River Water Management District

PROJECT NO: 91034 Figure 1-2

2.0 TECHNICAL APPROACH

The geophysical approach taken to achieve the objectives, stated in Section 1.0, was to determine the geoelectric section of the subsurface, and to infer from that section information about water quality. The resistivity of a water bearing rock is mainly a function of lithology, dissolved solids in ground water, and porosity. Most rock forming minerals are essentially insulators and nearly all electrical current is carried either by free ions in pore water or by exchangeable ions associated with clay particles. To separate the causes of vertical and lateral variation in a geoelectric section requires careful correlation with lithology, and often assumptions about the dominant cause of resistivity variation locally must be made. For the 14 sites in the SJRWMD variation in lithology is mainly expected in the Hawthorn Group and younger surficial units. The composition of these formations can vary from coarse-grained sands and gravels to clays. Thus, in the Hawthorn Group and younger sediments three factors potentially can influence resistivity, - lithology (clay content), porosity and water quality. Without other independent information the causes of lateral and vertical resistivity variation cannot be separated, and no attempt has been made to infer information about water quality from resistivity measurements for the formations above the Floridan aquifer. However, at some sites, one average value of resistivity is obtained for the Hawthorn Group which is typically 100 ft to 200 ft thick, and several hundred feet of the Upper Floridan. In those situations the resistivity obtained probably closely correspond to the real resistivity of the carbonate rocks of the Upper Floridan aquifer.

On the other hand, the lithology of the carbonate rocks comprising the Floridan aquifer system are expected to be uniform. The resistivity of the rocks of the Floridan aquifer will be mainly determined by porosity and dissolved solids concentrations of the pore fluids. Archie's Law is used to express the relationship between formation resistivity, Ro; fluid resistivity, Rw; and porosity, ϕ:

$$F = Ro/Rw = a\ \phi^{-m} \qquad [1]$$

where F = formation factor and a,m are empirically derived constants dependent on lithology and pore type distribution. Kwader (1986) found a value of m = 1.6 and a = 1 to best fit his many observations from wells completed in the Upper Floridan aquifer in Seminole County.

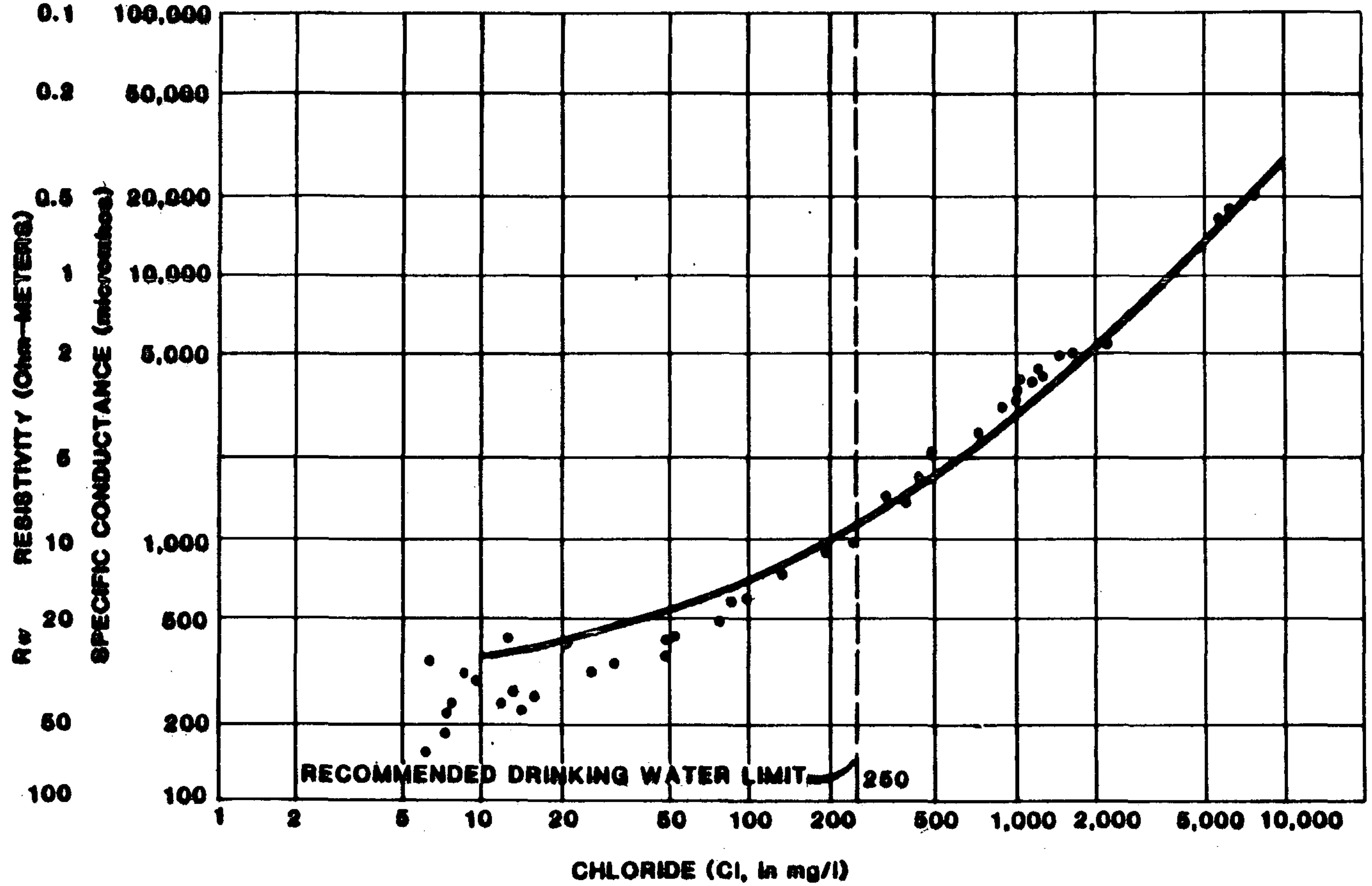
Fluid resistivity is a function of concentration of dissolved solids and ionic composition. The most common cations in water in the Upper Floridan aquifer are calcium, magnesium and sodium; the most common anions are bicarbonate, chloride and sulfate. Water quality is often expressed in terms of equivalent chloride concentrations. Kwader (1968) established on the basis of many measurements on water samples throughout Seminole County the relation between chloride concentration and fluid resistivity, Rw, given by

$$CL = 3500/Rw - 153 \qquad [2]$$

where CL is chloride concentration in mg/l, and Rw is fluid resistivity in ohm-meter.

A graphic presentation of this relation is given in Figure 2-1, and it also shows the data points from which relation [2] was derived. The maximum chloride concentrations for which data points were available to Kwader (1986) was about 10,000 mg/l, and the relation is untested at higher chloride concentrations.

By combining equation [1] and [2] chloride concentration can be related to formation resistivity as a function of porosity, and this relation is displayed in Figure 2-2. Thus, for the Upper Floridan aquifer with an average porosity of 25%, chloride concentrations less than 250 mg/l are expected when its formation resistivity is greater than 80 ohm-m. Chloride concentrations



(After: Kwader, 1986)

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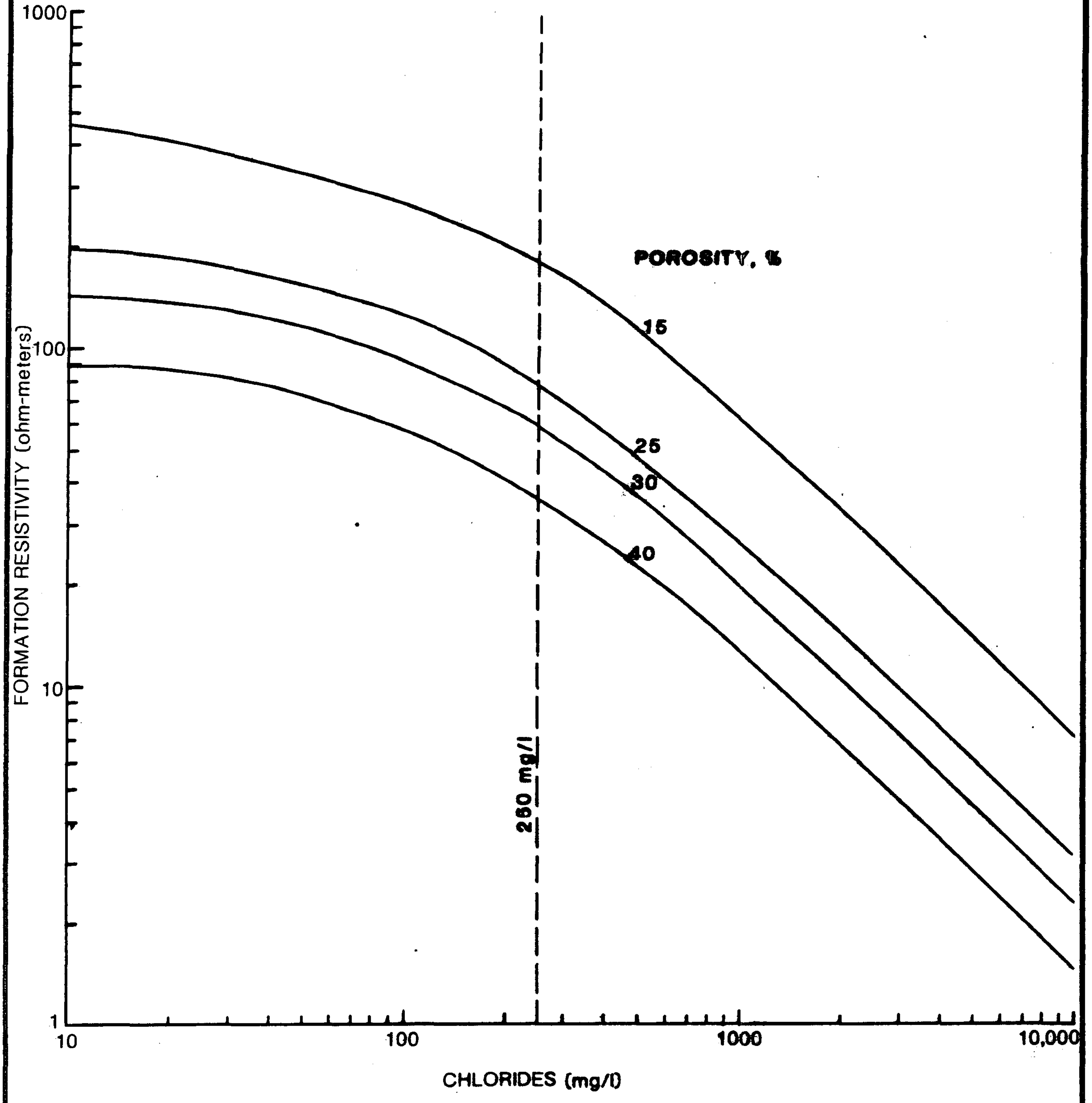
FLUID RESISTIVITY (Rw) VERSUS CHLORIDE CONCENTRATION

St. Johns River Water Management District

PROJECT NO: 91034

Figure 2-1



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FORMATION RESISTIVITY VERSUS CHLORIDE CONCENTRATION

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

PROJECT NO: 91034

Figure 2-2

greater than 1,000 mg/l would be indicated by formation resistivity values less than about 28 ohm-m, and greater than 10,000 mg/l at formation resistivities less than about 3.2 ohm-m.

It is evident from the above discussion that to derive chloride concentration from a measured value of formation resistivity certain assumptions must be made. The assumptions consistently made for all 14 sites are:

a) The relation (Fig. 2-1) between fluid resistivity and chloride concentration established by Kwader (1986) for Seminole County is valid also for the 14 sites surveyed in the SJRWMD;

b) In deriving chloride content from formation resistivity an average porosity of 25% was used for all sites. Information about porosity of the Floridan aquifer is limited. In one published data set, porosities were computed from geophysical logs over the depth interval between 338 ft and 458 ft. Porosities over this depth range varied between 12% to 32% (NW Florida Water Management District, 1983). Since site specific information about porosities was not available, a porosity value of 25% has been used at all sites.

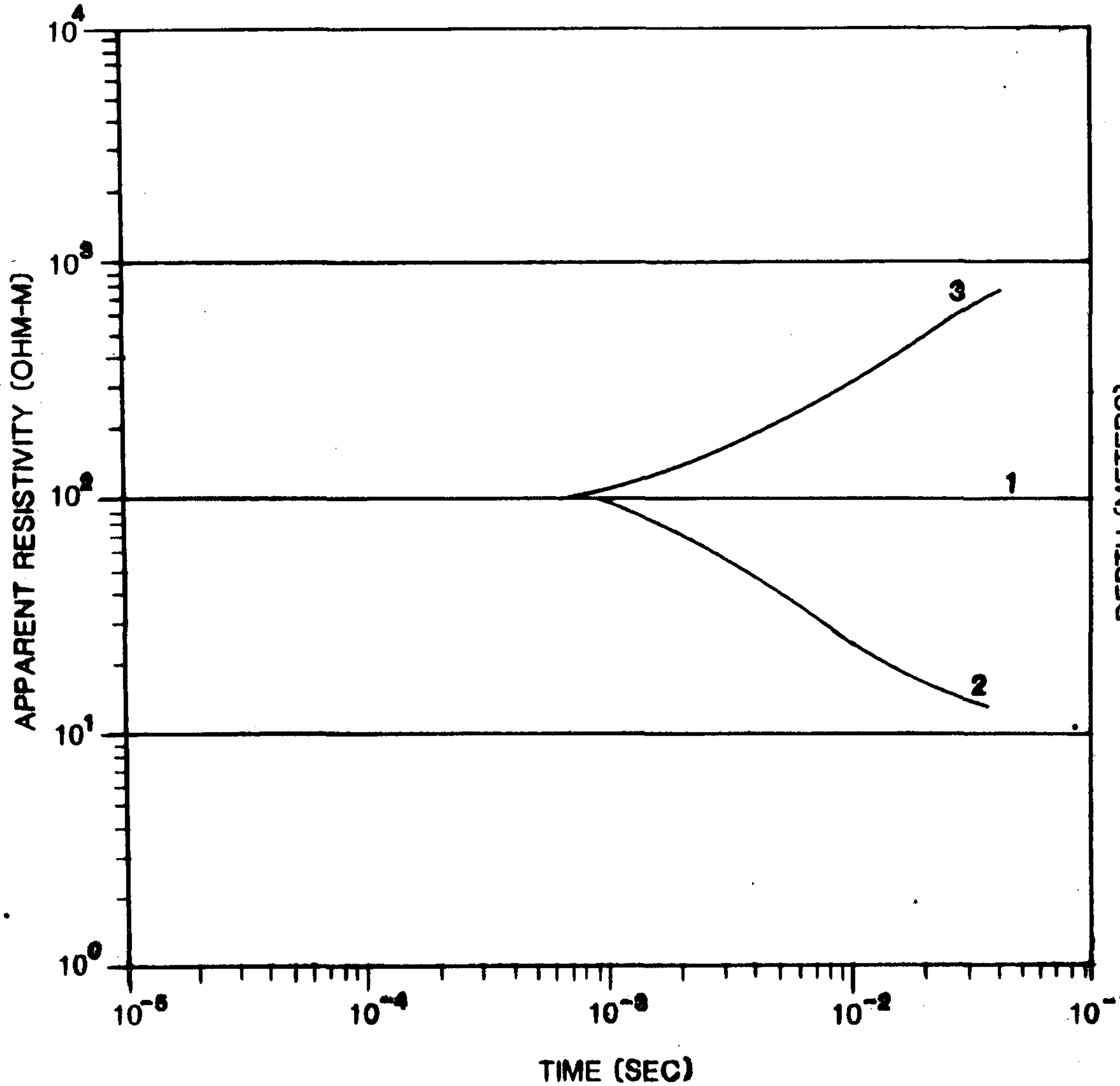
c) In the Hawthorn Group, resistivity values are influenced by changes in lithology, porosity, and chloride concentration. This precluded inferring meaningful interpretations about chloride concentrations in the Hawthorn Group. Inferences about water quality are, therefore, ideally drawn only for the carbonate rocks below the Hawthorn Group, and for each site an evaluation must be made of the extent clay stringers in the Hawthorn Group may have influenced the average resistivity value measured. Therefore, if a first layer is resolved in the geoelectric section that is less than 300 ft thick, it likely mainly consists of surficial sediments and the Hawthorn Group, and no information about equivalent chloride concentration can be inferred for such layer.

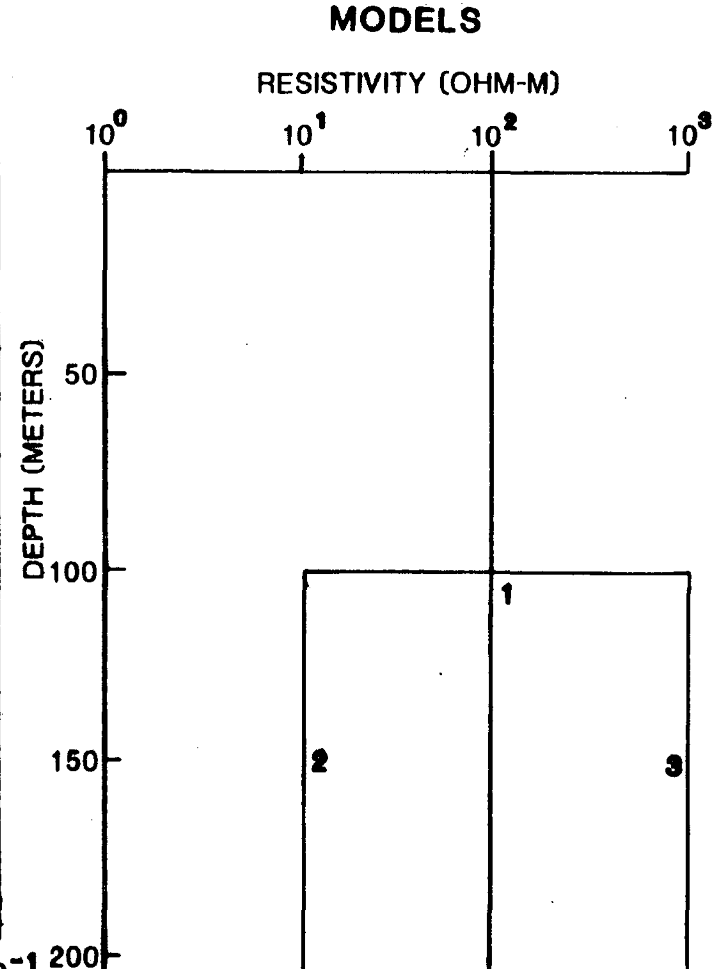
Measuring the Geoelectric Section

There are several electrical and electromagnetic methods that can determine from the surface the geoelectric section of the subsurface. These various methods vary in lateral and vertical resolution, and sensitivity to geologic noise. The method selected at the 14 sites throughout the SJRWMD was time domain electromagnetic (TDEM) soundings. The TDEM method was selected because (i) for the objectives at hand it has better lateral and vertical resolution and lower sensitivity to geologic noise than other methods, and (ii) it has proven effective for achieving similar objectives in prior surveys in the SJRWMD and other locations. The principles of TDEM soundings are discussed in the technical note in Appendix A. In this section only the deliverables of a TDEM sounding are reviewed. These deliverables are the same for each site.

It is common in all electrical and electromagnetic methods to transform the voltages and electromotive forces measured into apparent resistivities. The reason for that transformation is to better visualize how the geoelectric section, over which a measurement is made, differs from a geoelectric section with an uniform resistivity. This transformation is also made in TDEM, so that for each site an apparent resistivity curve is shown.

Figure 2-3 shows three computed apparent resistivity curves for three different geoelectric sections. In TDEM effective exploration depth increases with time of measurement after turn-off (Appendix A). In model 1 the resistivity is uniform with depth and the apparent resistivity is constant over the entire time interval. In model 2 true resistivity decreases with depth, and the apparent resistivity curves reflect that. The apparent





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MODELED APPARENT RESISTIVITY CURVES

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 2-3**

resistivities can be seen to decrease with increasing time. In model 3 the resistivity increases with depth and at later time the apparent resistivity curve also shows an increase. Thus, qualitative information about the geoelectric section can be visualized from displaying the data as apparent resistivities.

The function of an apparent resistivity curve can be further explained for sounding 03-01 from site 3 at Wekiva River (Fig. 2-4). The apparent resistivity values can be seen to continuously decrease with increasing time, and to asymptotically approach a value between 10 ohm-m and 20 ohm-m. Thus, from merely viewing the behavior of the apparent resistivity curve, the conclusions can be drawn that (i) the resistivities decrease with depth, and (ii) the resistivity of the lowest layer within the effective exploration depth of the measurement is between 10 ohm-m and 20 ohm-m.

To derive more quantitative information the experimental data points are submitted to an automatic ridge regression inversion program. This inversion program finds the geoelectric section of the subsurface that best matches the observed data. The inversion program requires an initial model for the geoelectric section. A model consists of the number of layers within the effective exploration depth, and the resistivities and thicknesses for each layer. Such an initial model can be obtained in a number of ways, such as

- approximate matching of apparent resistivity curves with model curves from albums of model curves
- from knowledge of the geoelectric section based on resistivity logs run in drill holes
- from conceptual models formed on the basis of known geology and water quality.

The inversion program is then allowed to adjust the model to improve the fit. This involves the adjustment of resistivities and thicknesses of the layers within the geoelectric model. The inversion program does not change the total number of layers submitted for the model, but all other parameters float freely or optionally can be held constant. To determine the influence of number of layers on the solution, separate inversions with a different number of layers may be run.

The geoelectric section obtained from the inversion routine that best matches the experimental data is shown on the right side of Figure 2-4. It consists of a two-layer geoelectric section consisting of an upper layer 87.6 m thick with a resistivity of 50.4 ohm-m. The second layer has a resistivity of 14.2 ohm-m and its thickness extends beyond the effective exploration depth of the measurement. The solid line on Figure 2-4 represents the computed behavior for the two-layer geoelectric section shown on the right, and the experimental data are superimposed on the solid line.

To evaluate the error between the geoelectric section derived from the inversion routine and the experimental data, a tabulation of the inversion and experimental data is also given for each site. The parameters listed on these tables are identified in Table 2-1 for sounding 03-01. Thus, this table lists the error (column 4) between experimental measurements (data, column 2) and calculated data (column 3) for each time gate of measurement (column 1). Also listed on the table is the root mean square (RMS) averaged over all time gates.

Analysis of Equivalence

The parameters derived for the geoelectric section by the ridge regression inversion are not unique, but generally a range of values will equally fit the observed data within the overall RMS error. This phenomena is called equivalence, and the range of equivalence differs for each parameter of

03-01

MODEL: 2 LAYERS

RESISTIVITY	THICKNESS	ELEVATION		CONDUCTANCE (S)	
(OHM-M)	(M)	(M)	(FEET)	LAYER	TOTAL
		12.2	40.0		
50.36	87.6	-75.4	-247.3	1.7	1.7
14.19					

Solution Geoelectric Section

Inversion Table

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	5.46E+02	5.36E+02	1.955	
2	1.10E-04	4.24E+02	4.14E+02	2.399	
3	1.40E-04	3.21E+02	3.15E+02	1.981	
4	1.77E-04	2.46E+02	2.46E+02	0.182	
5	2.20E-04	1.94E+02	1.97E+02	-1.253	
6	2.80E-04	1.51E+02	1.55E+02	-2.519	
7	3.55E-04	1.20E+02	1.23E+02	-3.069	
8	4.43E-04	9.80E+01	1.01E+02	-2.880	
9	5.64E-04	8.08E+01	8.16E+01	-0.902	
10	7.13E-04	6.75E+01	6.70E+01	0.826	
11	8.81E-04	5.75E+01	5.72E+01	0.541	
12	1.10E-03	4.99E+01	4.91E+01	1.570	
13	1.41E-03	4.32E+01	4.17E+01	3.603	
14	1.80E-03	3.78E+01	3.64E+01	4.045	
15	2.22E-03	3.42E+01	3.28E+01	4.404	
16	2.83E-03	2.94E+01	2.93E+01	0.574	
17	3.55E-03	2.56E+01	2.68E+01	-4.320	
18	4.43E-03	2.43E+01	2.49E+01	-2.452	
19	5.64E-03	2.32E+01	2.30E+01	0.983	
20	7.13E-03	2.20E+01	2.18E+01	1.075	
21	8.81E-03	2.06E+01	2.07E+01	-0.497	
22	1.10E-02	1.96E+01	1.97E+01	-0.497	
23	1.41E-02	1.86E+01	1.89E+01	-1.604	
24	1.80E-02	1.76E+01	1.82E+01	-3.485	
25	2.22E-02	1.70E+01	1.77E+01	-4.029	
26	2.85E-02	1.80E+01	1.72E+01	4.460	
27	3.60E-02	1.72E+01	1.68E+01	2.225	

R: 237. X: 0. Y: 237. DL: 475. REQ: 264. CF: 1.0000

TDHZ ARRAY, 27 DATA POINTS, RAMP: 190.0 MICROSEC, DATA: 03-01

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EXAMPLE INVERSION TABLE

WEKIVA RIVER

SITE 3

St. Johns River Management District

PROJECT NO: 91034 Table 2-1

RMS Error

RMS LOG ERROR: 1.66E-02, ANTILOG YIELDS 3.8953 %

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

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

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

Result of Computation of Equivalence

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	46.620	50.357	54.730
	2	13.612	14.189	14.831
THICK	1	79.931	87.560	94.326
DEPTH	1	79.931	87.560	94.326

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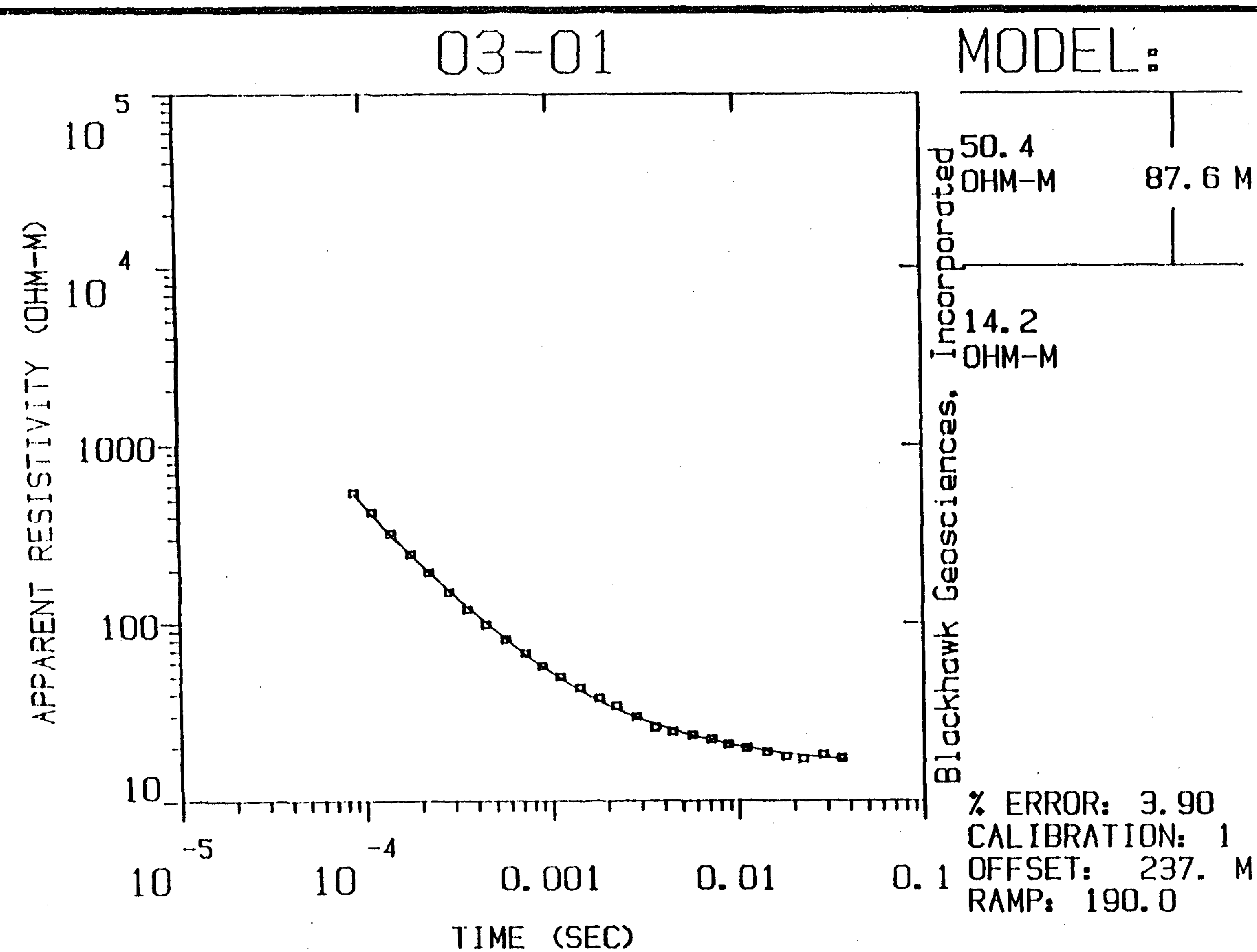
EXAMPLE INVERSION TABLE

WEKIVA RIVER

SITE 3

St. Johns River Management District

PROJECT NO: 91034 **Table 2-1**



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MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

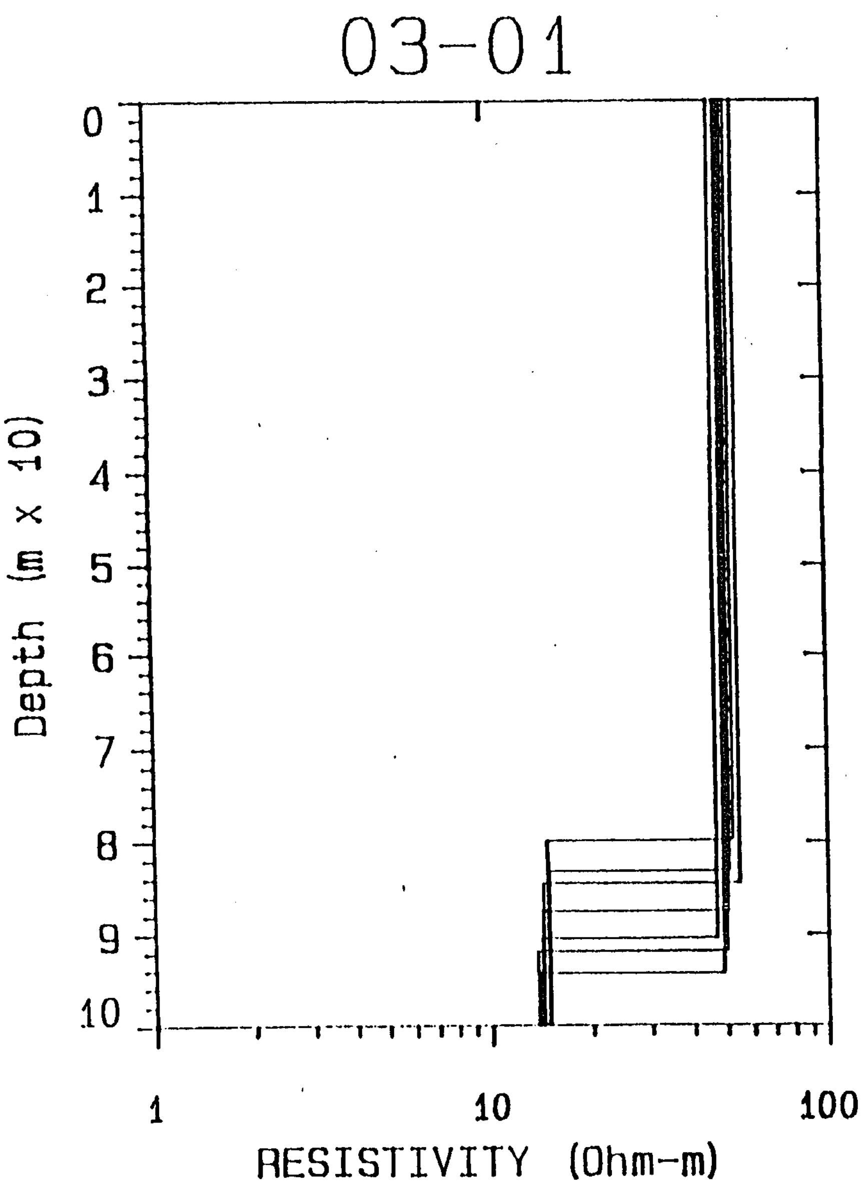
WEKIVA RIVER
SITE 3
St. Johns River Water Management District

PROJECT NO: 91034 | Figure 2-4

a geoelectric section. It is a measure of how well each parameter is resolved, and for each sounding the equivalence was evaluated.

The equivalence analysis for sounding 03-01 is shown on Figure 2-5, and the upper and lower bound for each parameter of the geoelectric section is also shown on Table 2-1. Thus, at this site the largest range of equivalence is in determining the depth to the second layer. It may vary from 80 m to 94 m and still result in the same RMS error. The ranges of equivalence for the resistivities of the first and second layer are relatively small.

Examination of the equivalence of the 14 sites throughout the SJRWMD reveals that ranges of equivalence are dependent on the particular geoelectric section encountered. Also when the number of layers increases, the range of equivalence of some parameters in the section may be quite large.



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EQUIVALENCE IN 1-D INVERSION

WEKIVA RIVER

SITE 3

St. Johns River Water Management District

PROJECT NO: 91034

Figure 2-5

3.0 LOGISTICS, DATA PROCESSING AND INTERPRETATION

Logistics and Equipment

The general locations for TDEM measurements were determined by SJRWMD. Using the general locations, BGI personnel positioned the transmitter loops and receiver station with compass and measuring string. The transmitter loop locations were selected to mitigate to the maximum extent possible against interferences caused by buried pipelines, other utility lines, fences, power lines and buildings. The transmitter loops were formed of 12-gauge insulated wire laid out in either a square or rectangle on the surface. Dimensions of the loops were determined by the depth of exploration required and availability of open land. At sites 7, 8 and 9 loop sizes of 200 ft by 200 ft were employed, and at the remaining sites the transmitter loop sizes ranged from 1,000 ft by 1,000 ft to 1,500 ft by 1,500 ft, depending on access. Most of the transmitter loops were square in shape, but in some cases access required that rectangular loops be used. The actual dimensions of the transmitter loops at each sounding location are shown on the location maps in Section 4.2 through 4.15. The locations of the loops were plotted on maps by SJRWMD personnel.

The TDEM equipment utilized on the survey was the Geonics EM-37. Some of the characteristics of that instrument are discussed in Appendix A. Table 3-1 summarizes the daily field activities. The field crew consisted of three persons, a two person BGI crew consisting of one geophysicist and one geophysical technician, and a representative of SJRWMD was also present during the field work.

Table 3-1. Daily log of field activities.

Date (1991)	Activity
August 12	Mobilize from Denver, CO to Eustis, FL.
August 13	Read sounding at Site 1 (Wekiva Springs State Park).
August 14	Read soundings at Site 2 (Rock Springs State Preserve) and Site 4 (Simpson Training Center).
August 15	Read sounding at Site 3 (Wekiva River).
August 16	Read additional sounding at Site 4 (Simpson Training Center) and read sounding at Site 5 (Royal Trails).
August 17	Read sounding at Site 6 (Ormond Beach West Well Field).
August 18	Read soundings at Sites 7 (Astronaut High School), 8 (North Brevard Waste Water Treatment Plant), and 9 (Parrish Grove).
August 19	Read sounding at Site 10 (New Smyrna Beach Western Well Field).
August 20	Read sounding at Site 11 (Orange County Landfill).
August 21	Read sounding at Site 12 (Deseret Ranch).
August 22	Read soundings at Sites 13 (Lake Mary) and 14 (Wekiva Springs Road).
August 23	Demobilize from Orlando, FL to Denver, CO.

Data Acquisition

At all stations the electromotive force (emf) due to the vertical magnetic field in the center of transmitter loops was recorded at several amplifier gains and opposite receiver polarities. Receiver coils with effective areas of 100 m^2 and 1,000 m^2 were employed. The data were recorded at base frequencies of 3 Hz and 30 Hz. The current driven through the transmitter loops varied from 13 amps to 24 amps, depending on loop size. All data was recorded on a DAS-54 data logger.

Mitigation of Inductive Noise Sources

A concern in the acquisition of TDEM data is to recognize interferences caused by induction in metallic structures, such as buried utility lines, fences, grounded power lines and buildings. The primary magnetic field of a transmitter induces eddy current flow in such structures, and these eddy currents in turn cause a secondary magnetic field. That secondary magnetic field can interfere with TDEM measurements, and because it is coherent with the transmitter, it cannot be removed by stacking.

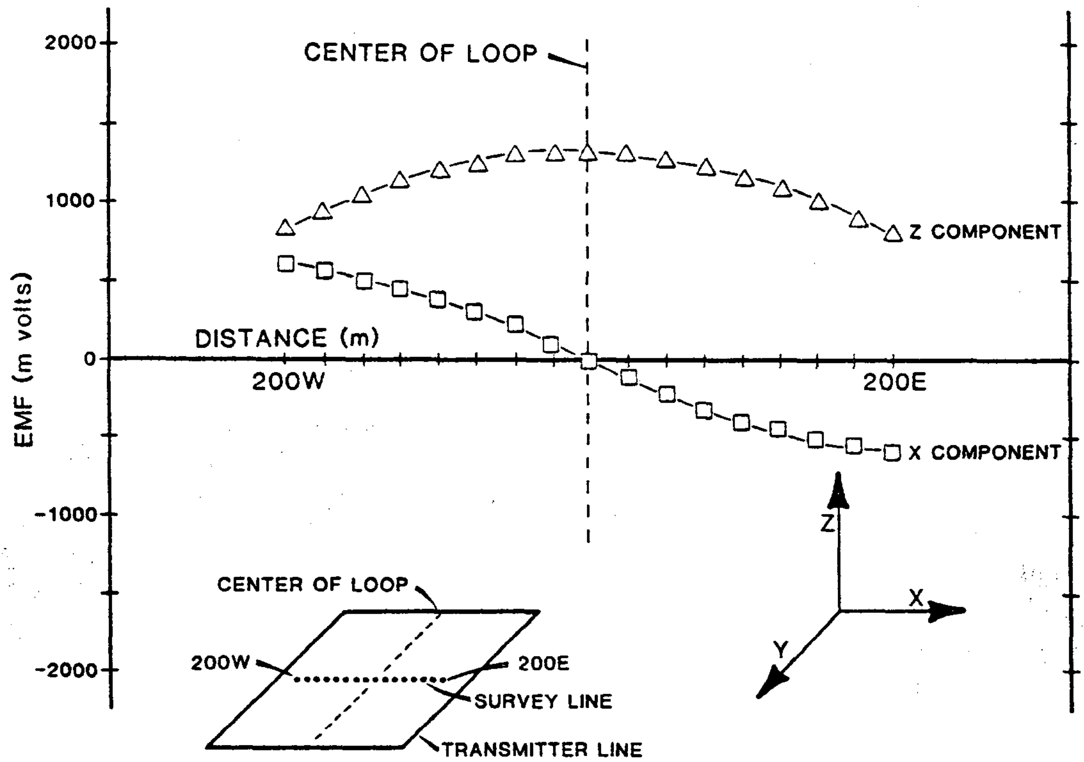
The influence of these inductive noise sources, however, can be recognized from anomalies caused in the spatial behavior of the fields. Figure 3-1 shows a typical behavior of the emf due to the vertical magnetic field on a profile through the center of the loop. This data is typical of that observed over layered ground. Figure 3-1 shows that emf_z is relatively flat on a profile through the center of the loop. Measurements at different locations within the loop should nearly coincide for measurements over layered ground. This is illustrated in Figure 3-2 where apparent resistivity curves for soundings at five different locations in the center of the loop have been superimposed. The data virtually coincide and from that observation the conclusion is drawn that inductive noise is minimum.

Figure 3-3 on the other hand shows an example of five data sets measured at different locations within the loop with considerable deviation between the data sets. The cause of deviation is inductive interference by metallic structures, and the best way to mitigate this noise is to reposition the transmitter loop to minimize this effect.

Data Processing

The data stored in the DAS-54 solid memory logger was transferred each day to floppy disks on a computer. The first step in data processing was to average the emf's recorded at opposite receiver polarities. Next, the recordings at different amplifier gains and frequencies are combined to produce one transient decay. The emf's in the various time gates of this decay curve are subsequently entered into a ridge regression inversion program to obtain a one-dimensional geoelectric section that matches the observed decay curve.

SPATIAL BEHAVIOR OF EMFS



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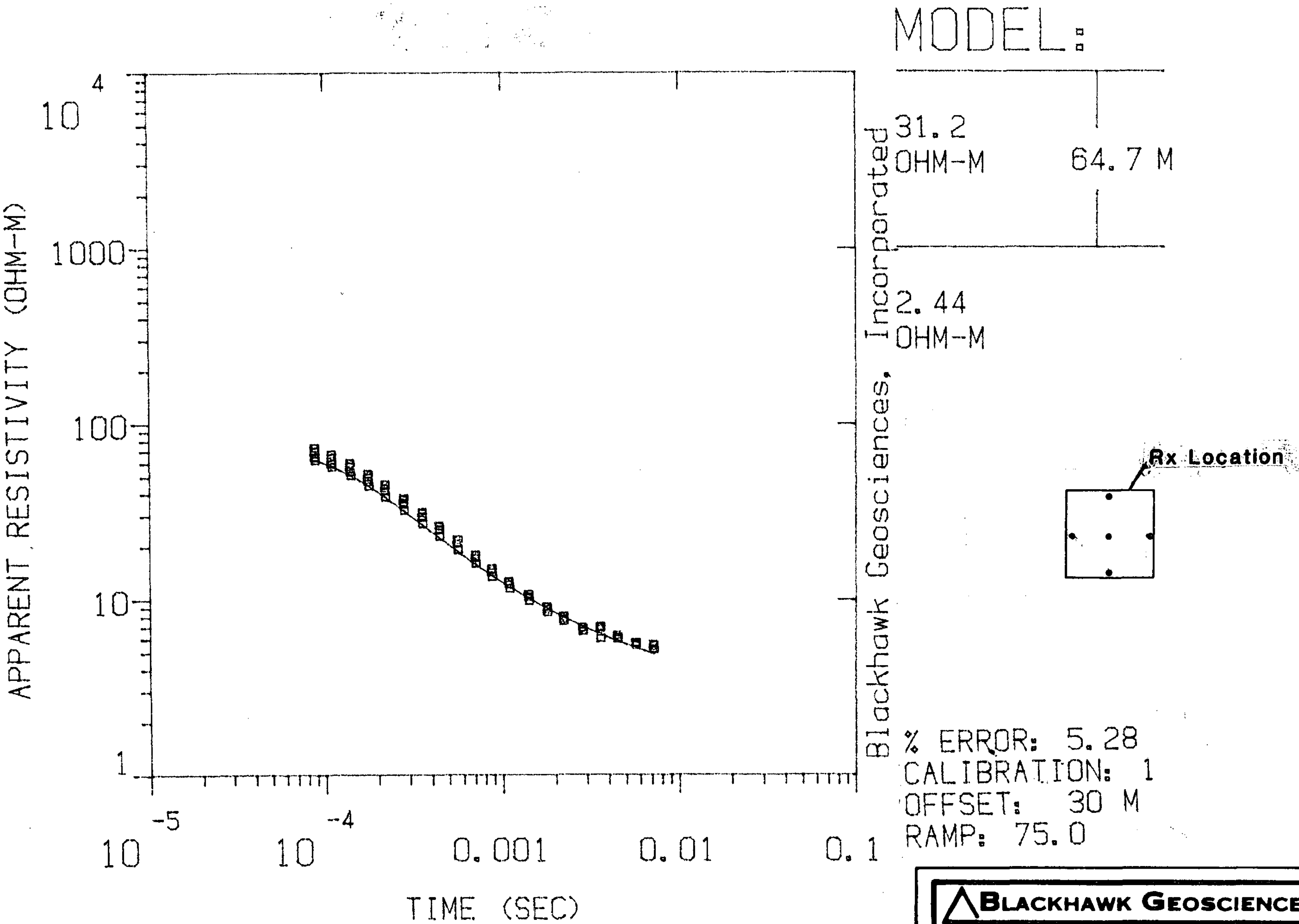
SPATIAL BEHAVIOR OF EMFz AND EMFx ON PROFILE THROUGH CENTER OF LOOP

St. Johns River Management District

PROJECT NO: 91034 **Figure 3-1**



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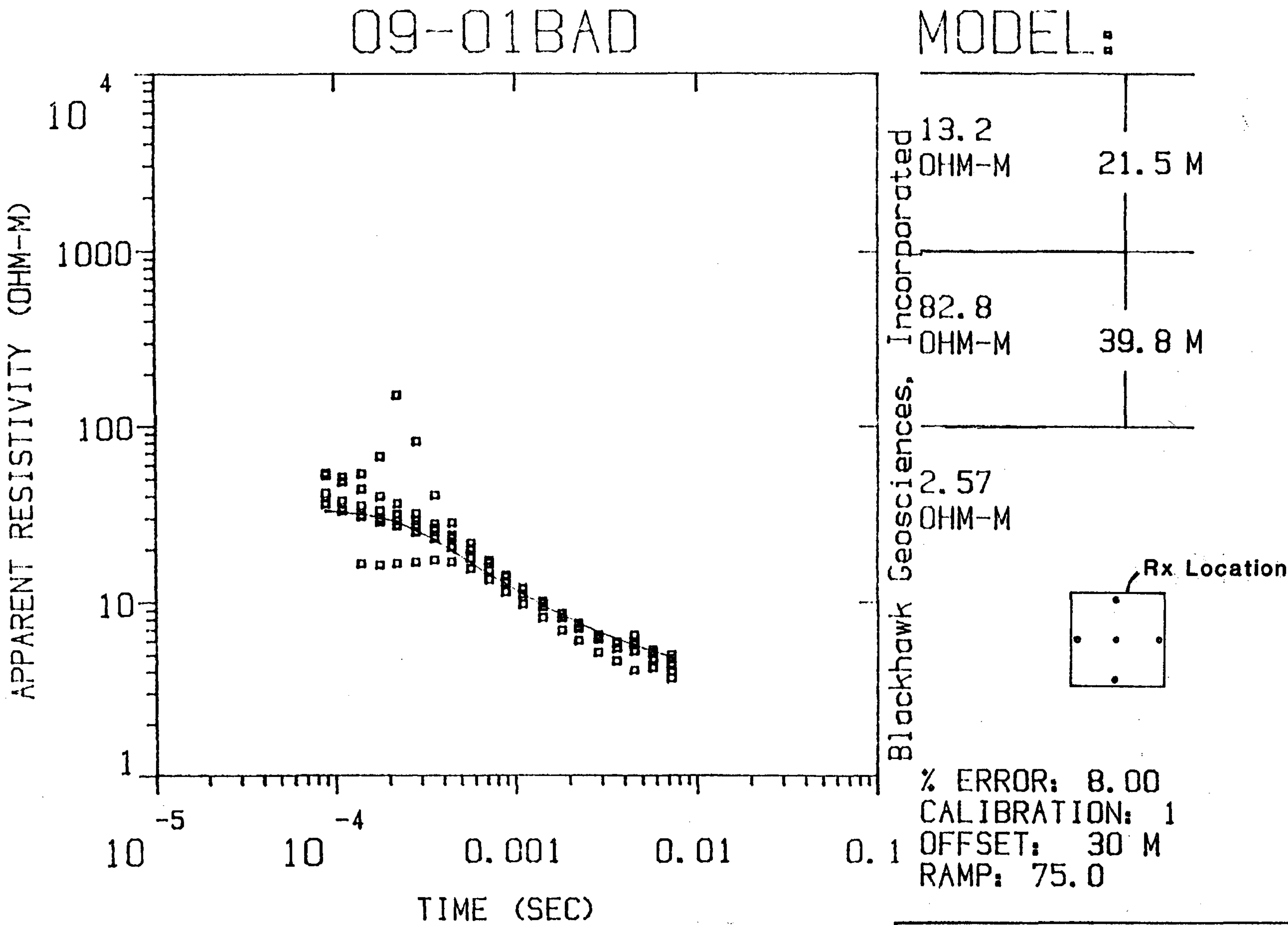
DATA UNAFFECTED BY CULTURE

ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 **Figure 3-2**



BLACKHAWK GEOSCIENCES, INC.

DATA AFFECTED BY CULTURE

ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 **Figure 3-3**

4.0 *RESULTS AND DISCUSSION*

4.1 SUMMARY OF RESULTS

In Sections 4.2 through 4.15 the results of the TDEM measurements at the 14 sites are given. In these sections first the geoelectric section is shown, and subsequently information about first depth of occurrence of highly saline water, water quality in the Upper Floridan aquifer where possible, and depth of occurrence of the 250 mg/l isochlor is inferred from the geoelectric section. In this section the results of all 14 sites are summarized.

Table 4-1.1 lists the sites, the dimensions of the transmitter loops employed, the County in which the site is located, and the longitude and latitude of the center of the loop. In Table 4-1.2 the geoelectric section measured at each site is summarized. It first lists the number of layers of different resistivities used in the inversion. This number corresponds to the number of distinct resistivity boundaries resolved with surface TDEM within the effective exploration depth of the measurement. For each parameter of the geoelectric section (resistivities and thicknesses) the range of equivalences are given in terms of the minimum and maximum value this parameter can assume, and the "best" value.

Table 4-1.3 summarizes the first depth of occurrence of ground water with a chloride concentration greater than 1,000 mg/l. Since information about chloride concentration is derived from resistivity values, the correlation of resistivities to chloride concentrations require assuming a value of porosity. In Table 4-1.3 chloride concentrations are derived for three porosity values - 25%, 30% and 35%. The depth to saline water listed on Table 4-1.3 is expected to represent the top of the boundary between ground water of chloride concentrations less than 1,000 mg/l and ground water with chloride concentrations greater than 1,000 mg/l. Likely chloride concentrations gradually increase below this interface, and gradually decrease above it. The inversion of TDEM data can, at present, only resolve distinct boundaries, and transition zones are not mapped. The depth listed likely represent some average depth within the transition zone.

Water quality measurements were available from a number of sampled wells near TDEM soundings (Toth et al, 1989). The location of these wells is shown on various figures for the individual sites. Table 4-1.4 lists the chloride, hardness, sulfate, and iron concentrations in these wells for the periods of April 1973 to July 1974, and March 1986 and October 1986. The data in this table are referred to on several occasions in discussing the results of individual sites.

Table 4-1.1 __Geographic information about measurement sites__

Site Name	Site #	County	Loop Size (ft)	Latitude	Longitude
Wekiva Springs State Park	1	Orange	1250 x 1500	28^0 44' 10"	81^0 28' 53"
Rock Springs State Preserve	2	Orange	1250 x 1450	28^0 45' 40"	81^0 26' 52"
Wekiva River	3	Lake	1400 x 1600	28^0 49' 23"	81^0 25' 39"
Simpson Training Center	4-1	Lake	1100 x 1400	28^0 50' 59"	81^0 32' 08"
	4-2	Lake	500 x 500	28^0 50' 55"	81^0 32' 04"
Royal Trails	5	Lake	1000 x 1300	28^0 56' 52"	81^0 26' 29"
Ormond Beach West Well Field	6	Volusia	1200 x 1400	29^0 11' 07"	81^0 12' 53"
Astronaut High School	7	Brevard	200 x 200	28^0 37' 27"	80^0 50' 53"
North Brevard WWTP	8	Brevard	200 x 200	28^0 41' 54"	80^0 52' 43"
Parrish Grove	9	Brevard	200 x 200	28^0 40' 39"	80^0 50' 53"
New Smyrna Beach West Wellfield	10	Volusia	1400 x 1500	29^0 01' 09"	81^0 07' 38"
Orange County Landfill Site	11	Orange	1500 x 1600	28^0 28' 05"	81^0 13' 17"
Deseret Ranch	12	Orange	1500 x 1500	28^0 23' 20"	81^0 00' 51"
Lake Mary	13	Seminole	1100 x 1100	28^0 46' 07"	81^0 20' 38"
Wekiva Springs Road	14	Lake	950 x 950	28^0 47' 56"	81^0 25' 52"

Table 4-1.2
Summary of Geoelectric Sections with Range of Equivalence

Site Name	Number of Modeled Layers in Geoelectric Section	Layer 1						Layer 2						Layer 3						Layer 4		
		ρ_1 Resistivity (ohm-meters)			Thickness h_1(meters)			ρ_2 Resistivity (ohm-meters)			Thickness h_2(meters)			ρ_3 Resistivity (ohm-meters)			Thickness h_3(meters)			ρ_4 Resistivity (ohm-meters)		
		Min	Best	Max	Min	Best	Max	Min	Best	Max	Min	Best	Max	Min	Best	Max	Min	Best	Max	Min	Best	Max
(1) Wekiva Springs State Park	2	53	54	56	61	63	66	550	640	780												
(2) Rock Springs State Preserve	3	29	31	33	120	140	150	220	1100	12,000	150	170	180	14	16	18						
(3) Wekiva River	2	47	50	55	80	88	94	14	14	15												
(4) Simpson Training Center	3	36	48	69	24	41	77	190	465	2568	129	154	174	4.1	6.8	11.4						
(5) Royal Trails	4	64	78	88	57	90	130	180	240	410	310	360	400	1.7	3.3	6.4	18	44	110	20	25	33
(6) Ormond Beach West Well Field	3	30	39	51	13	23	48	92	98	110	290	320	330	1.9	2.3	2.7						
(7) Astronaut High School	2	27	30	32	53	55	57	2.3	2.5	2.7												
(8) North Brevard WWTP	2	33	35	38	55	56	57	1.5	1.6	1.6												
(9) Parrish Grove	2	29	31	33	62	65	67	2.2	2.4	2.7												
(10) New Smyrna Beach West Wellfield	3	30	35	38	61	80	100	110	150	310	180	210	230	7.3	9.0	11.0						
(11) Orange County Landfill Site	3	31	33	34	80	88	98	440	710	1300	620	640	660	7.2	11	16						
(12) Deseret Ranch	3	58	190	1900	9.9	17	28	25	26	27	340	400	460	6.2	9.4	14						
(13) Lake Mary	3	43	60	81	21	37	64	240	290	390	320	340	370	4.4	5.5	6.8						
(14) Wekiva Springs Road	3	21	23	25	32	43	57	45	49	55	230	250	270	7.2	8.7	10.0						

Table 4-1.3

First Depth of Occurrence and Chloride Concentration of Layer with Chloride Concentrations Greater than 1,000 mg/l Inferred From Geoelectric Section Derived from TDEM Soundings

	Site	Formation Resistivity (ohm-m)	First Depth of Occurrence (ft below surface)	Estimated Chloride Concentration (mg/l) at 3 Porosities		
				Porosity		
				25%	30%	35%
(1)	Wekiva Springs State Park	Not Detected				
(2)	Rock Springs State Preserve	16	1002	1,850	1,340	1,010
(3)	Wekiva River	14	287	2,140	1,540	1,170
(4)	Simpson Training Center	6.8	639	4,580	3,490	2,690
(5)	Royal Trails	3.3	1465	9,590	7,130	5,540
(6)	Ormond Beach West Wellfield	2.3	1122	>10,000	>10,000	8,010
(7)	Astronaut High School	2.5	181	>10,000	9,460	7,360
(8)	North Brevard WWTP	1.6	183	>10,000	>10,000	>10,000
(9)	Parrish Grove	2.4	212	>10,000	9,860	7,670
(10)	New Smyrna Beach WWF	9.0	949	3,420	2,520	1,930
(11)	Orange County Landfill	10.6	2389	2,882	2,110	1,620
(12)	Deseret Ranch	9.4	1355	3,270	2,400	1,840
(13)	Lake Mary	5.5	1248	5,700	4,210	3,260
(14)	Wekiva Springs Road	8.7	960	3,540	2,610	2,000

Table 4-1.4. Chloride, hardness, sulfate, and iron concentrations in sampled wells for the period April 1973 to July 1974, March 1986 and October 1986 (after Toth et al, 1989)

					Chlorides mg/l			Hardness mg/l			Sulfate mg/l			Iron µg/l		
COUNTY	WELL OWNER	WELL ID	LAT	LONG	Apr 73-Jul 74	Mar 86	Oct 86	Apr 73-Jul 74	Mar 86	Oct 86	Apr 73-Jul 74	Mar 86	Oct 86	Apr 73-Jul 74	Mar 86	Oct 86
Lake	Wekiva Falls	L-0048	284740	812517	240	296	300	370	400		200	210	230	0	50	20
	Wekiva Falls	L-0049	284740	812517		312	300		390			210	210			
	Woodard	L-0073	284747	812515		352	340		440			225	220		50	60
	Dorton's Barn	L-0047	284753	812621		57	71		190			50	57		188	540
	Mock	L-0076	284800	812523		244	220		370			190	190		50	120
	Major Realty	L-0038	284933	812558	282	176	220	420	308		165	145	150	210	452	430
Orange	Fl Wek. Pres.	OR0054	284541	812652	200	208	220	324	900		180	145	160	30	50	60
		OR0035	284429	812720	40	45	77	156	150		45	18	50	20	50	10

4.2 WEKIVA SPRINGS STATE PARK (SITE 1)

Location and Geoelectric Section

The detailed location of this sounding is shown in Figure 4-2.1. The interpreted geoelectric section is shown in Figure 4-2.2, and it consists of a two layer section. The resistivity of the upper layer is 54 ohm-m and it is 209 ft thick; the resistivity of the second layer is 640 ohm-m and its thickness extends beyond the effective exploration depth of the measurement.

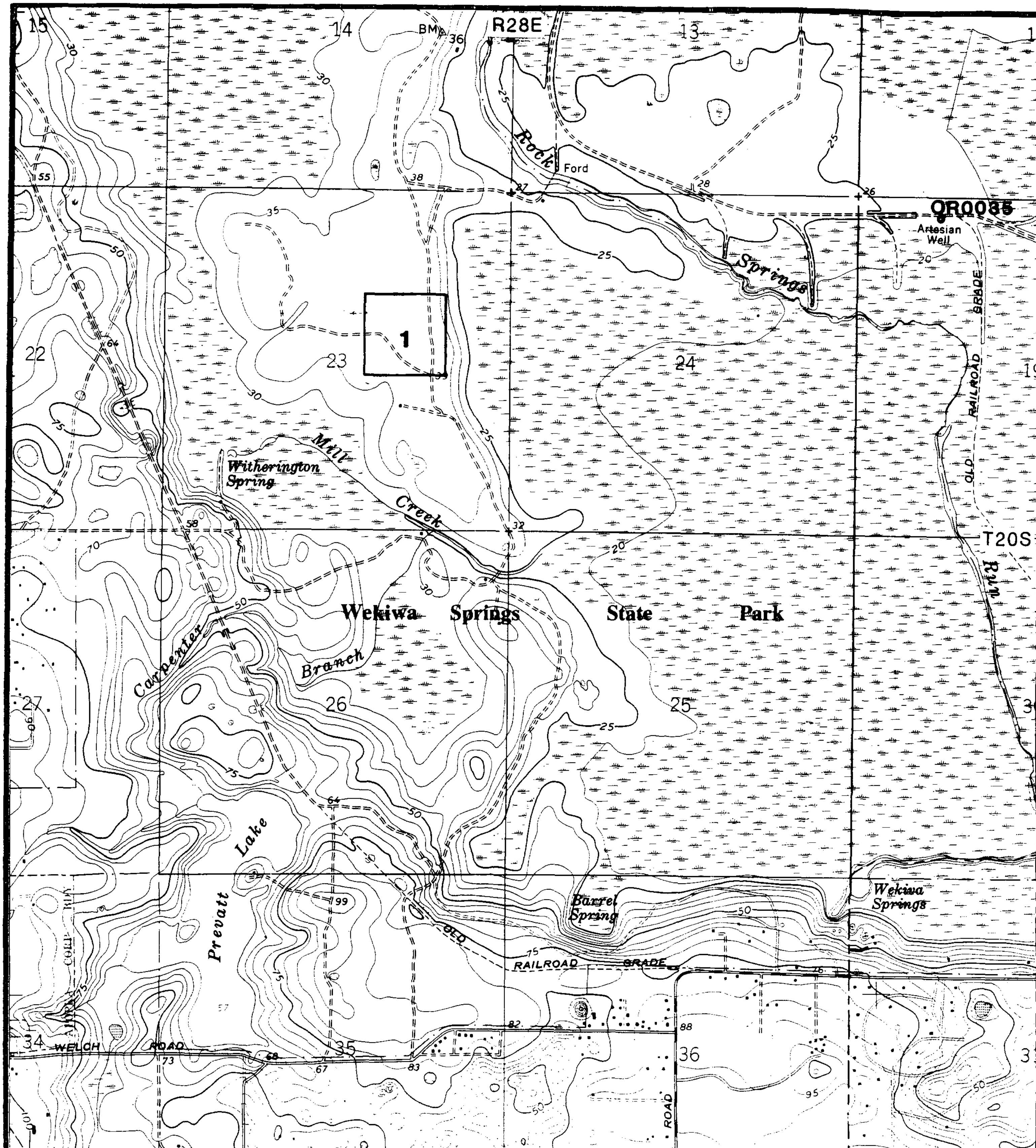
Depth of Occurrence of High Salinity Water

Thus, resistivity values characteristic of saline water were not encountered in this sounding within the effective exploration depth of the measurement. Since one objective of this TDEM survey is to determine the depth of occurrence of the interface with highly saline water, an evaluation was made of the minimum depth a layer of low resistivity would have been detected.

To estimate the minimum depth of occurrence of a low resistivity layer, a series of computations were made placing a low resistivity layer (characteristic of saline water) at various depths below the geoelectric section observed. The minimum depth at which model curves with this low resistivity layer inserted diverges from observed data, represents the effective depth of exploration. The effective exploration depth for detecting a layer with a resistivity of 5 ohm-m or less (more than 5,000 mg/l chloride) was computed to be approximately 2,500 ft. The effective exploration depth decreases somewhat for detecting strata of lower salinity. At a resistivity of 28 ohm-m corresponding to 1,000 mg/l chloride, the effective exploration is about 1,800 ft. The influence of salinity on effective exploration depth is shown in Table 4-2.1

Table 4-2.1. Influence of salinity and resistivity on effective exploration depth for detecting a unit of low resistivity placed below the geoelectric section observed at Site 1.

Resistivity of Unit of Low Resistivity (ohm-m) Placed Below Geoelectric Section Measured	Equivalent Chloride (mg/l) at 25% Porosity	Effective Depth of Exploration (ft) for Detecting Layer of Low Resistivity (high salinity)
2.7	10,000	2,500
5.0	5,000	2,500
10	3,000	2,150
20	1,200	2,000
80	250	1,500



1	TDEM Sounding

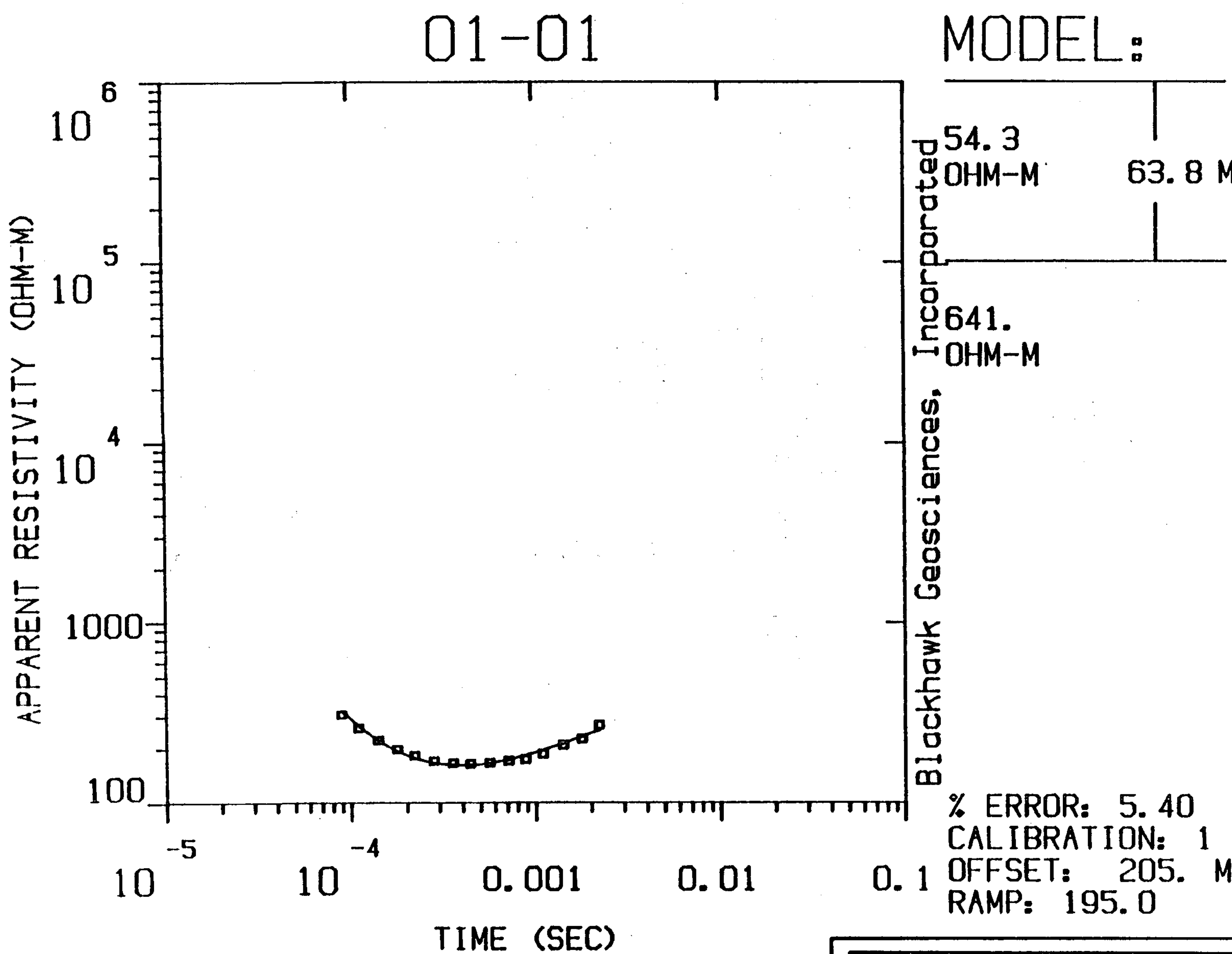
0 2000 4000 Feet

N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 1
WEKIVA SPRINGS STATE PARK
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 Figure 4-2.1



BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

WEKIVA SPRINGS STATE PARK

SITE 1

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-2.2**

Depth of Occurrence of 250 mg/l Isochlor

Another objective of the survey was to determine the depth to the 250 mg/l isochlor. The upper 209 ft with a resistivity of 54 ohm-m likely represents the Hawthorn Group and younger sediments, as well as a portion of the upper Ocala aquifer. The resistivity value of this layer is probably influenced as much by lithology as by chloride concentration. However, the resistivity value of 640 ohm-m below 209 ft is characteristic of the Upper Floridan aquifer from 209 ft below surface to about 1,500 ft below surface (see Table 4-2.1). The chloride concentration of the ground water below about 209 ft is expected to be lower than 250 mg/l based on a formation resistivity of 640 ohm-m, assuming an average porosity of 25%. Measurements in wells in the general area by Toth et al (1989) show the chloride concentration to be below 25 mg/l.

The depth of occurrence of the 250 mg/l isochlor is below the effective depth of exploration of the measurement. It was computed to occur at a depth greater than 1,500 ft below surface.

Accuracy of Measurement and Interpretation

Figure 4-2.3 shows the evaluation of equivalence of the TDEM sounding at this site, and the inversion table (Table 4-2.2) lists the upper and lower boundary of the parameters of the geoelectric section. The important parameter influencing the information about chloride concentration of the Upper Floridan aquifer is the resistivity of the second layer, and the value of that resistivity is determined to be between 550 ohm-m and 776 ohm-m. That range of resistivity is well above the value of 80 ohm-m below which, at an average porosity of 25%, chloride concentrations greater than 250 mg/l are expected (Fig. 4-2.2). The conclusion, inferred from the measurements, that the chloride concentration between 209 ft and 1,500 ft below surface is less than 250 mg/l, is not influenced by accuracy of measurements.

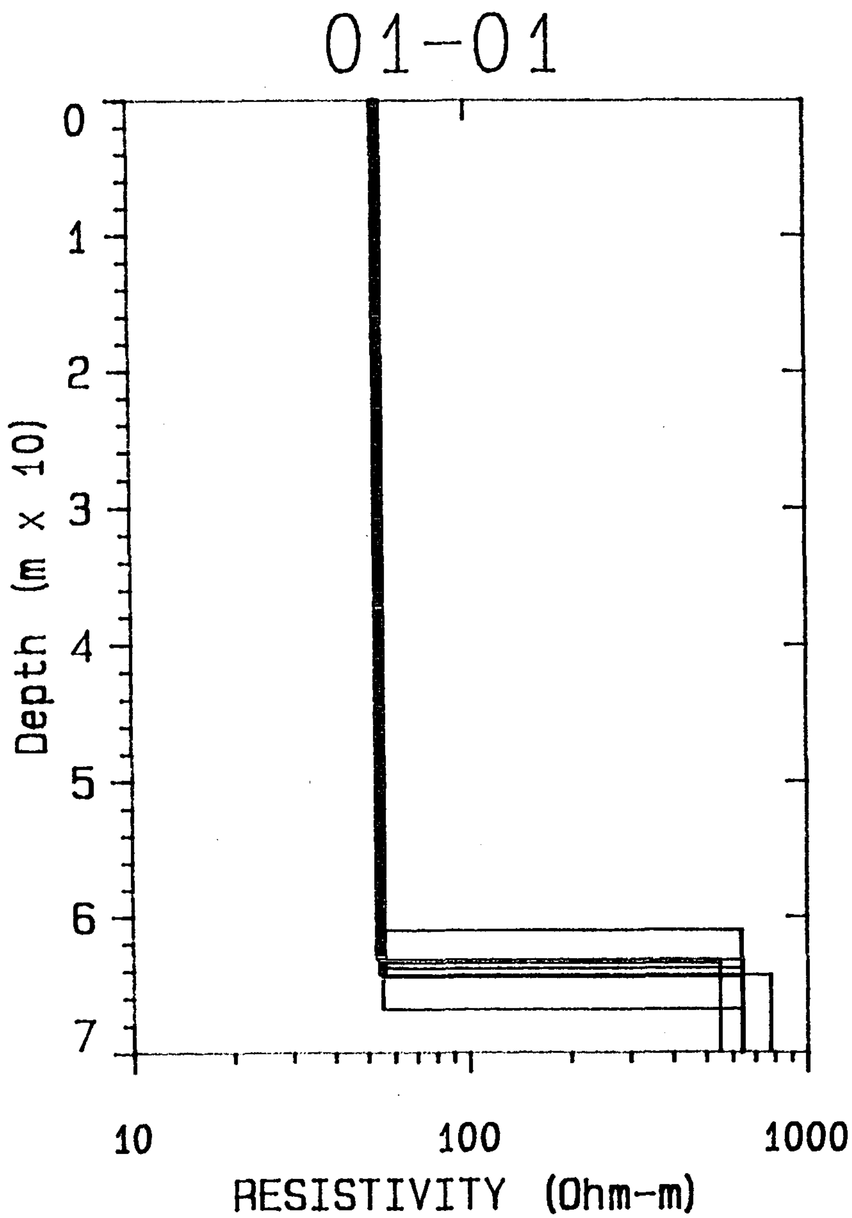
Accuracy of measurements, however, is but one factor influencing validity of the conclusions reached. More important may be the validity of the assumptions made. To conclude that the 250 mg/l isochlor occurs at a depth of 1,500 ft below surface assumes that the average porosity remains near 25%, and the validity of that assumption cannot be tested.

Summary of Results of TDEM Measurements at the Wekiva Springs State Park

From the TDEM measurements the following information about water quality was inferred:

1) The depth of occurrence of highly saline water was beyond the effective exploration depth of the measurements. With computer modeling, the minimum depth of occurrence of ground water with a chloride concentration of 1,000 mg/l was determined to be about 1,800 ft.

2) The chloride concentration in the Upper Floridan aquifer between a depth of 209 ft and 1,500 ft below surface was inferred to be less than 250 mg/l. The depth of occurrence of the 250 mg/l isochlor was inferred to be below 1,500 ft below surface.



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

WEKIVA SPRINGS STATE PARK

SITE 1

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-2.3**

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		10.7	35.0		
54.28	63.8	-53.2	-174.5	1.2	1.2
641.08					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	3.06E+02	3.25E+02	-5.616	
2	1.10E-04	2.58E+02	2.66E+02	-3.048	
3	1.40E-04	2.21E+02	2.21E+02	-0.034	
4	1.77E-04	1.97E+02	1.93E+02	2.364	
5	2.20E-04	1.83E+02	1.76E+02	3.667	
6	2.80E-04	1.70E+02	1.66E+02	2.971	
7	3.55E-04	1.66E+02	1.61E+02	2.831	
8	4.43E-04	1.64E+02	1.61E+02	1.814	
9	5.64E-04	1.66E+02	1.65E+02	0.493	
10	7.13E-04	1.71E+02	1.73E+02	-1.174	
11	8.81E-04	1.74E+02	1.83E+02	-4.824	
12	1.10E-03	1.87E+02	1.96E+02	-4.339	
13	1.41E-03	2.09E+02	2.13E+02	-1.734	
14	1.78E-03	2.26E+02	2.32E+02	-2.383	
15	2.21E-03	2.69E+02	2.51E+02	7.239	

R: 205. X: 0. Y: 205. DL: 409. REQ: 228. CF: 1.0000
TDHZ ARRAY, 15 DATA POINTS, RAMP: 195.0 MICROSEC, DATA: 01-01
WEKIVA SPRINGS STATE PARK

RMS LOG ERROR: 2.28E-02, ANTILOG YIELDS 5.4013 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.31		
P 2	0.04	0.01	
T 1	-0.23	-0.04	0.18
	P 1	P 2	T 1

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE
WEKIVA SPRINGS STATE PARK
SITE 1
St. Johns River Management District

PROJECT NO: 91034 **Table 4-2.2**

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	52.698	54.277	55.910
	2	550.121	641.082	776.137
THICK	1	61.054	63.848	66.847
DEPTH	1	61.054	63.848	66.847

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

WEKIVA SPRINGS STATE PARK

SITE 1

St. Johns River Management District

PROJECT NO: 91034 **Table 4-2.2**

4.3 ROCK SPRINGS STATE PARK (SITE 2)

Location and Geoelectric Section

The location of the Rock Springs sounding is shown in Figure 4-3.1. The interpreted geoelectric section is shown in Figure 4-3.2 and it consists of three layers. The upper layer with a resistivity of 31 ohm-m is 455 ft thick, the second layer is 547 ft thick and displays a resistivity of 1,088 ohm-m. The lower layer has a resistivity of 16 ohm-m and extends to the effective exploration depth of the measurements.

Geologic Interpretation of Geoelectric Section

The upper layer of 31 ohm-m likely represents surficial sediments, the Hawthorn Group, and portions of the upper Floridan aquifer. The transition from 31 ohm-m to 1,088 ohm-m may relate to the middle semi-confining unit reported (Tibbals 1990) to occur in this general area at a depth of about 375 ft below surface. The discrepancy in depth between 375 ft reported by Tibbals (1990) and the resistivity boundary at 455 ft may be due to (i) the regional information displayed by Tibbals (1990) versus the local measurements of the TDEM sounding, and (ii) resistivity boundaries may reflect both changes in porosity as well as salinity which two parameters need not necessarily coincide.

Depth of Occurrence of High Salinity Water

The lowest resistivity encountered in the geoelectric section is 16 ohm-m, and the top of this layer occurs at a depth of 977 ft below msl. Assuming an average porosity for the carbonate rocks of 25%, the chloride content of ground water at that depth is expected to be in excess of 1,850 mg/l (Fig. 2-2).

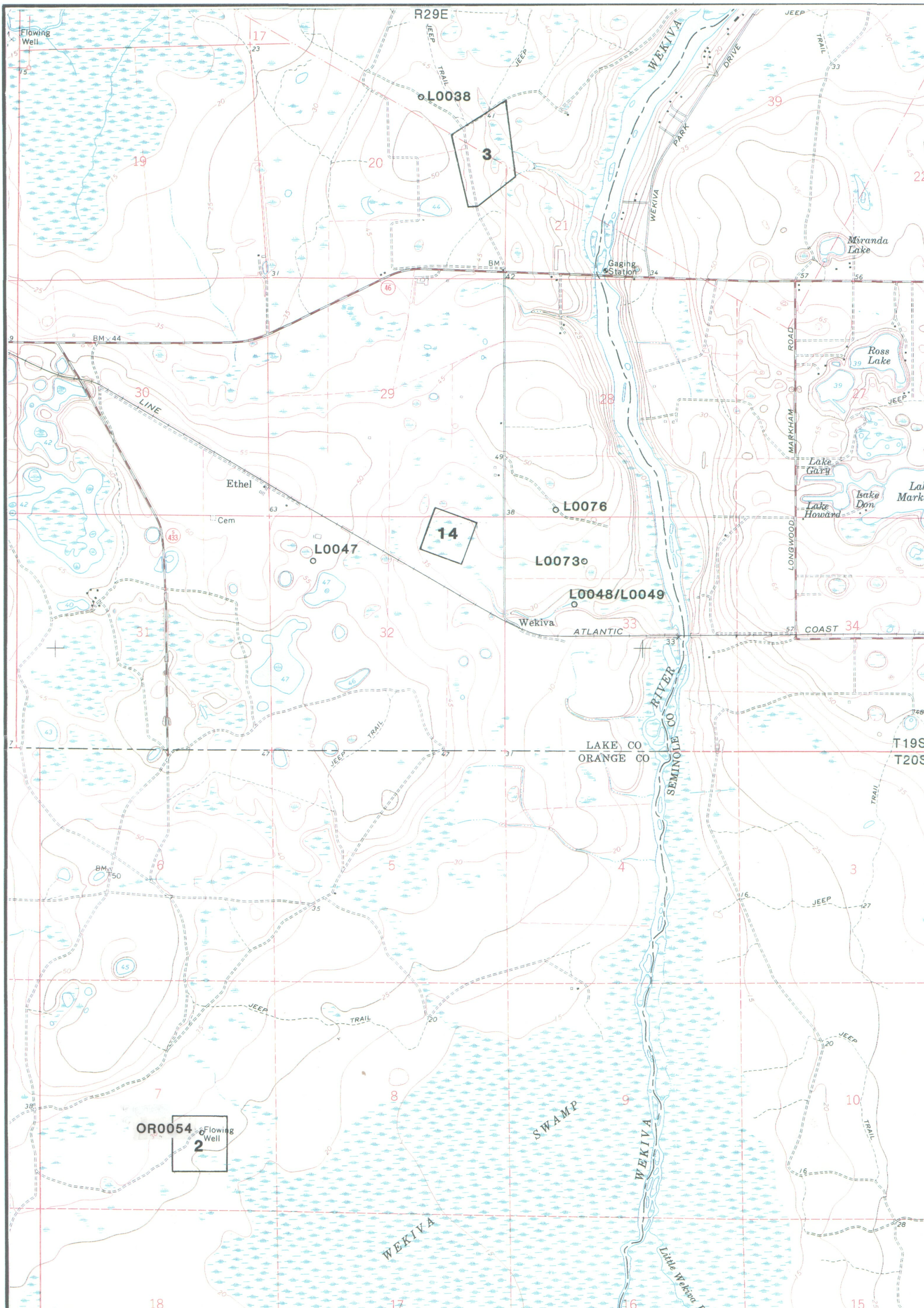
Depth of Occurrence of 250 ppm Isochlor

The upper layer in the geoelectric section has a resistivity of 31 ohm-m. This layer likely represents surficial sediments and the Hawthorn Group, as well as portions of the Upper Floridan aquifer. Because this layer appears several hundred feet thicker than the Hawthorn Group and younger sediments, the resistivity of 31 ohm-m likely also is characteristic of the first few hundred feet of the carbonate rocks of the Upper Floridan aquifer. Assuming an average porosity of 25%, 31 ohm-m corresponds to chloride concentrations in excess of 500 mg/l chloride. Toth et al (1989) measured chloride concentrations between 208 and 220 mg/l in March and October of 1986. In addition, he observed sulfate concentrations between 145 to 160 mg/l. The water quality measured in the wells shown on the map in Figure 4-3.1 are given in Table 4-1.4.

There is thus a discrepancy between chloride concentration inferred from the geoelectric section measured with TDEM and measured in wells by Toth et al (1989). Reasons for this disagreement might be:

1) The resistivity of 31 ohm-m for the upper 455 ft, which includes surficial sediments, the Hawthorn Group, and the Upper Floridan, may be influenced by some clay layers in both the Hawthorn Group and surficial sediments which would lower the resistivity.

2) In inferring chloride concentration from formation resistivity an average porosity of 25% is assumed, and the chemical position of the ground water is assumed similar to that measured by Kwader (1986) for wells in Seminole County. The relative high levels of sulfates measured by Toth et al (1989) indicate that the chemical composition of the ground water at site 2 may differ from the wells on which the data in Figures 2-1 and 2-2 are based.



1 TDEM Sounding

N

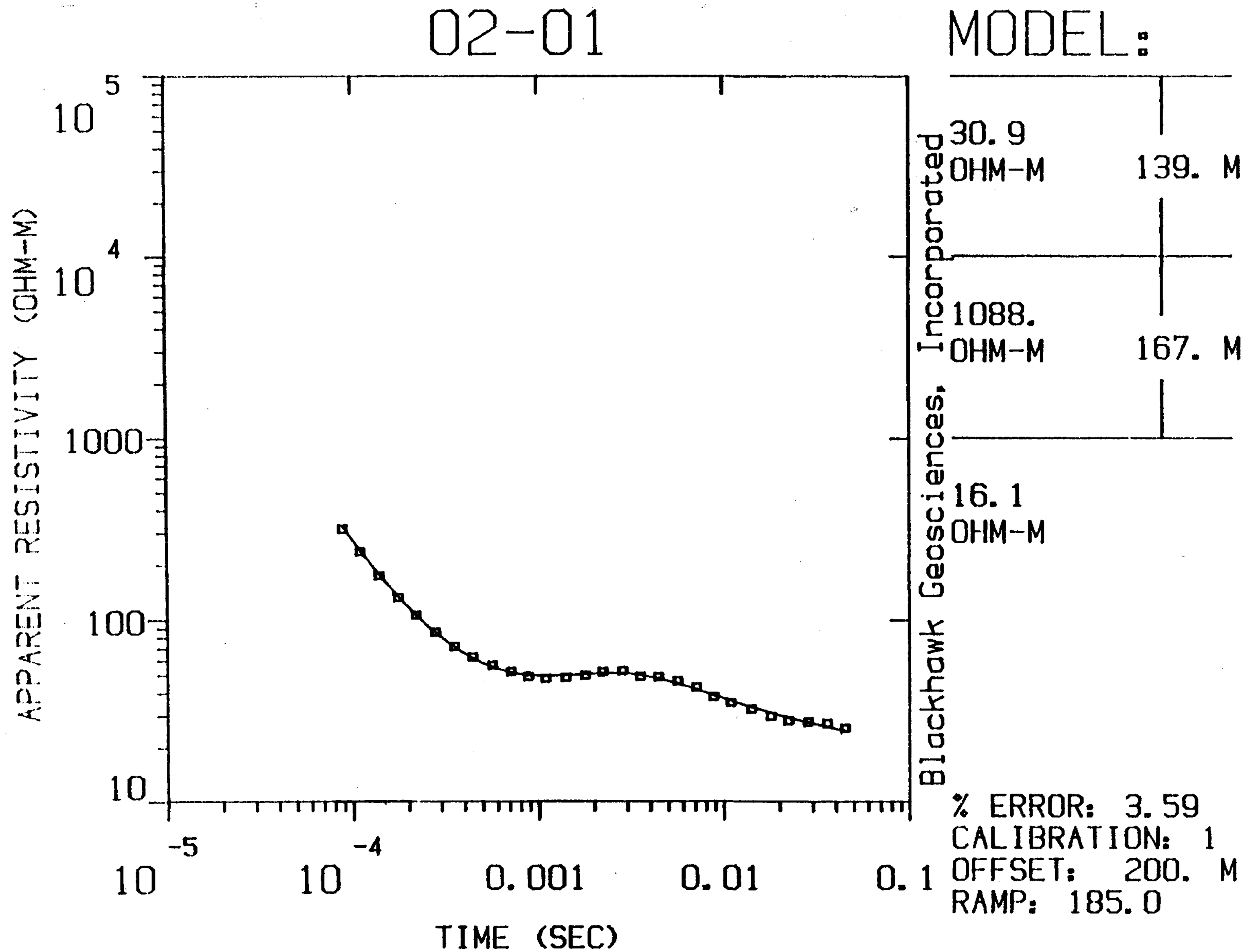
0 2000 4000 Feet

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 2,3,& 14
ROCK SPRINGS, WEKIVA RIVER
AND WEKIVA SPRINGS
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034

Figure 4-3.1



BLACKHAWK GEOSCIENCES, INC.

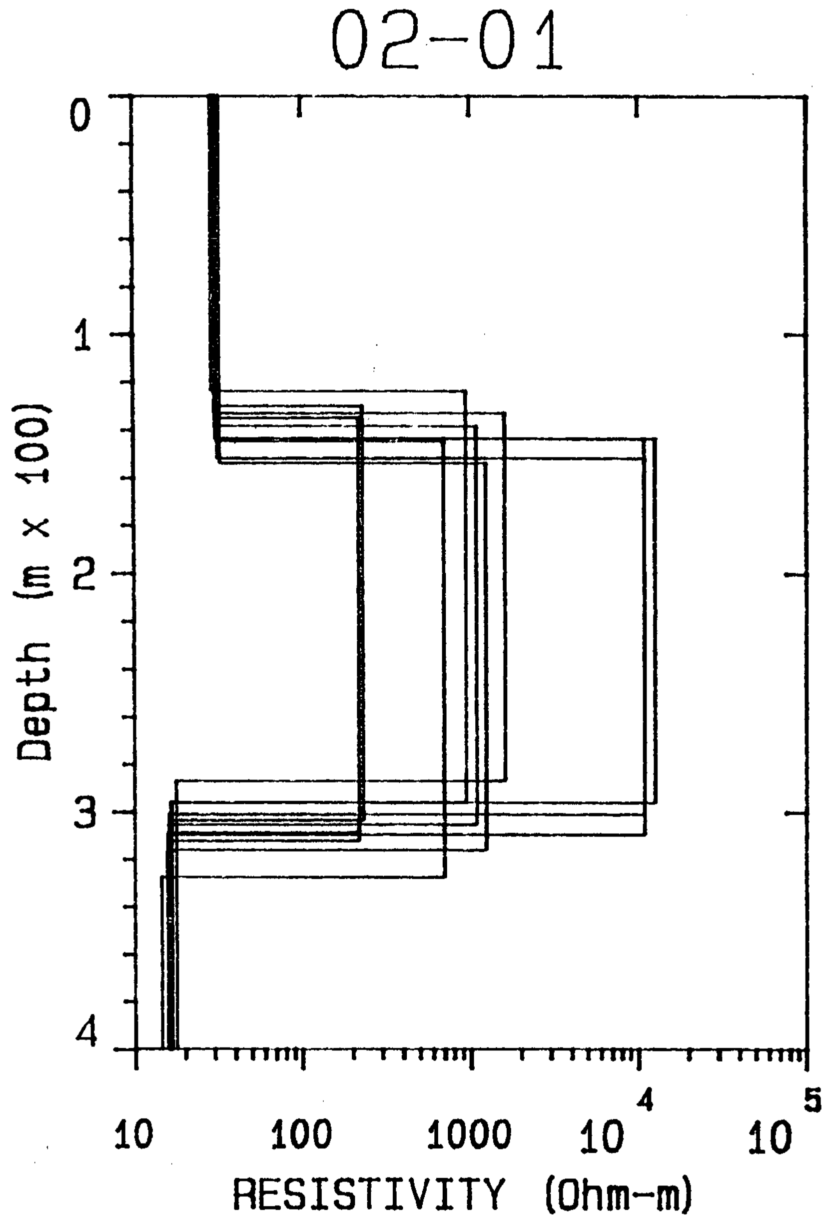
MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

ROCK SPRINGS STATE PARK

SITE 2

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-3.2**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

ROCK SPRINGS STATE PARK

SITE 2

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-3.3**

3) The time difference of approximately five years between measurements on wells and the TDEM survey.

Accuracy of Measurement and Interpretation

Figure 4-3.3 shows the evaluation of equivalence for the TDEM sounding at this site and the inversion table lists the upper and lower boundary of the parameters of the geoelectric section. The important parameter influencing information inferred about chloride concentration is the resistivity of the upper layer. The range of equivalence in the resistivity of that layer is between 29 ohm-m and 33 ohm-m. Variation in resistivity over that range does not negate the conclusion that the chloride concentration is expected to exceed 250 mg/l chloride in the Upper Floridan aquifer.

The main source of error in deriving water quality is not in the TDEM measurements, but in the assumptions necessary to infer from resistivity measurements information about chloride concentration.

Summary of Results of TDEM Measurements at the Rock Springs State Park (Site 2)

From the TDEM measurements the following information about aquifer characteristics and water quality was derived:

1) The depth of occurrence of saline water was interpreted to occur at elevations below 977 ft below msl. The chloride concentration at that depth is expected to exceed 1,850 mg/l.

2) On the basis of the resistivity value measured for the surficial sediments, the Hawthorn Group, and the Upper Floridan aquifer, the chloride concentration is expected to exceed 250 mg/l for the entire aquifer. This is, however, not consistent with water samples measured in wells in 1986 and reported by Toth et al (1989). They showed chloride concentrations just below 250 mg/l but also relatively high sulfate concentrations were measured. There also is a possibility that the resistivity value measured is influenced by clay stringers in the Hawthorn Group and younger sediments.

3) An increase in resistivity (from about 31 ohm-m to 1,088 ohm-m) is observed at a depth of 430 ft below msl. This change is interpreted to be related to a change in porosity in the carbonate rocks. It may represent a middle semi-confining unit.

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		7.6	25.0		
30.91	138.7	-131.1	-430.0	4.5	4.5
1088.34	166.8	-297.8	-977.1	0.2	4.6
16.08					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	3.16E+02	3.24E+02	-2.470	
2	1.10E-04	2.37E+02	2.42E+02	-2.150	
3	1.40E-04	1.75E+02	1.77E+02	-1.491	
4	1.77E-04	1.33E+02	1.34E+02	-1.347	
5	2.20E-04	1.06E+02	1.07E+02	-0.283	
6	2.80E-04	8.54E+01	8.51E+01	0.387	
7	3.55E-04	7.13E+01	7.07E+01	0.892	
8	4.43E-04	6.25E+01	6.16E+01	1.530	
9	5.64E-04	5.63E+01	5.51E+01	2.077	
10	7.13E-04	5.20E+01	5.14E+01	1.287	
11	8.81E-04	4.89E+01	4.96E+01	-1.380	
12	1.10E-03	4.78E+01	4.91E+01	-2.556	
13	1.41E-03	4.84E+01	4.95E+01	-2.291	
14	1.80E-03	4.98E+01	5.05E+01	-1.323	
15	2.22E-03	5.18E+01	5.11E+01	1.367	
16	2.85E-03	5.25E+01	5.11E+01	2.888	
17	3.55E-03	4.91E+01	4.99E+01	-1.695	
18	4.43E-03	4.87E+01	4.78E+01	1.812	
19	5.64E-03	4.62E+01	4.48E+01	3.212	
20	7.13E-03	4.28E+01	4.17E+01	2.637	
21	8.81E-03	3.81E+01	3.89E+01	-1.908	
22	1.10E-02	3.54E+01	3.62E+01	-2.244	
23	1.41E-02	3.27E+01	3.35E+01	-2.267	
24	1.80E-02	2.98E+01	3.12E+01	-4.325	
25	2.22E-02	2.82E+01	2.94E+01	-3.939	
26	2.85E-02	2.77E+01	2.76E+01	0.467	
27	3.60E-02	2.73E+01	2.61E+01	4.673	
28	4.49E-02	2.57E+01	2.49E+01	3.315	

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

ROCK SPRINGS STATE PARK

SITE 2

St. Johns River Management District

PROJECT NO: 91034 **Table 4-3.1**

R: 200. X: 0. Y: 200. DL: 400. REQ: 222. CF: 1.0000
TDHZ ARRAY, 28 DATA POINTS, RAMP: 185.0 MICROSEC, DATA: 02-01
ROCK SPRINGS STATE PRESERVE

RMS LOG ERROR: 1.53E-02, ANTILOG YIELDS 3.5855 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00				
P 2	0.00	0.01			
P 3	0.00	0.00	1.00		
T 1	0.00	-0.02	0.00	1.00	
T 2	0.00	0.03	0.00	0.00	1.00
	P 1	P 2	P 3	T 1	T 2

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	29.271	30.905	32.561
	2	219.345	1088.344	12556.611
	3	14.423	16.085	17.715
THICK	1	124.244	138.679	154.120
	2	152.240	166.771	182.799
DEPTH	1	124.244	138.679	154.120
	2	287.075	305.449	327.784

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE
ROCK SPRINGS STATE PARK
SITE 2
St. Johns River Management District

PROJECT NO: 91034 Table 4-3.1

4.4 WEKIVA RIVER (SITE 3)

Location and Geoelectric Section

The detailed location of this sounding is shown in Figure 4-4.1. The interpreted geoelectric section is shown in Figure 4-4.2, and consists of two layers. The upper layer has a resistivity of 50 ohm-m and a thickness of 287 ft. The lower layer has a resistivity of 14 ohm-m and was interpreted at a depth of 287 ft below surface or 247 ft below msl.

Geologic Interpretation of Geoelectric Section

The upper layer with a resistivity of 50 ohm-m and a thickness of 287 ft likely represents the Hawthorn Group and younger sediments, as well as a portion of the Upper Floridan aquifer.

Depth of Occurrence of High Salinity Water

The lowest resistivity encountered within the effective exploration depth of the measurement is 14 ohm-m, and it is first encountered at a depth of 247 ft below msl. Assuming an average porosity of 25%, the chloride concentration of ground water at that depth is expected to exceed 2,140 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

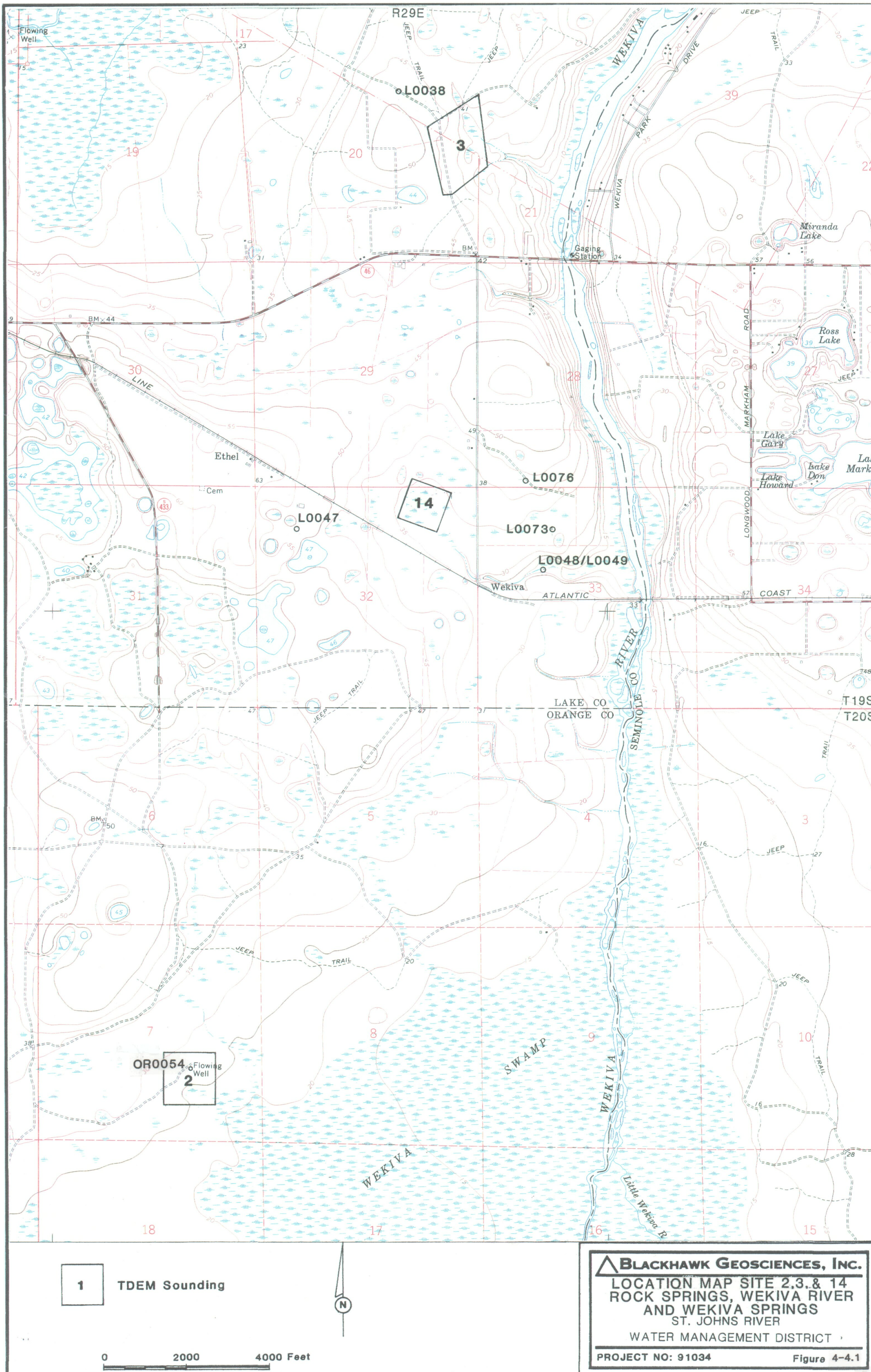
The upper layer in the geoelectric section has a resistivity of 50 ohm-m, and this layer is interpreted to be 287 ft thick. This layer likely includes part of the Upper Floridan aquifer below the Hawthorn Group. Even though this layer appears to be 100 ft to 200 ft thicker than the Hawthorn Group and younger sediments, the resistivity of 50 ohm-m may be influenced by clay layers in the Hawthorn Group and younger sediments. For that reason no information about chloride concentration has been inferred for this upper layer.

Toth et al (1989) in 1986 measured chloride concentrations between 176 mg/l (March) and 220 mg/l (October) in Well L-0038 nearby (Table 4-1.3). The sulfate concentrations for the same measurement periods were 145 mg/l and 150 mg/l.

Accuracy of Measurement and Interpretation

Figure 4-4.3 shows the evaluation of equivalence for the TDEM sounding at this site and the inversion table (Table 4-4.1) lists the upper and lower boundaries of the parameters of the geoelectric section. The important parameter influencing information inferred about chloride concentration is the resistivity of the upper layer. The range of equivalence in the resistivity of that layer is between 46 ohm-m and 55 ohm-m.

The main source of error in deriving water quality is not in the geophysical measurement, but in the assumptions necessary to infer from resistivity measurements information about chloride concentration. Since the resistivity of the first layer is expected to be influenced by clay layers in the Hawthorn Group and younger sediments, no information about chloride concentration is inferred for the first 100 ft to 150 ft of the Upper Floridan aquifer.

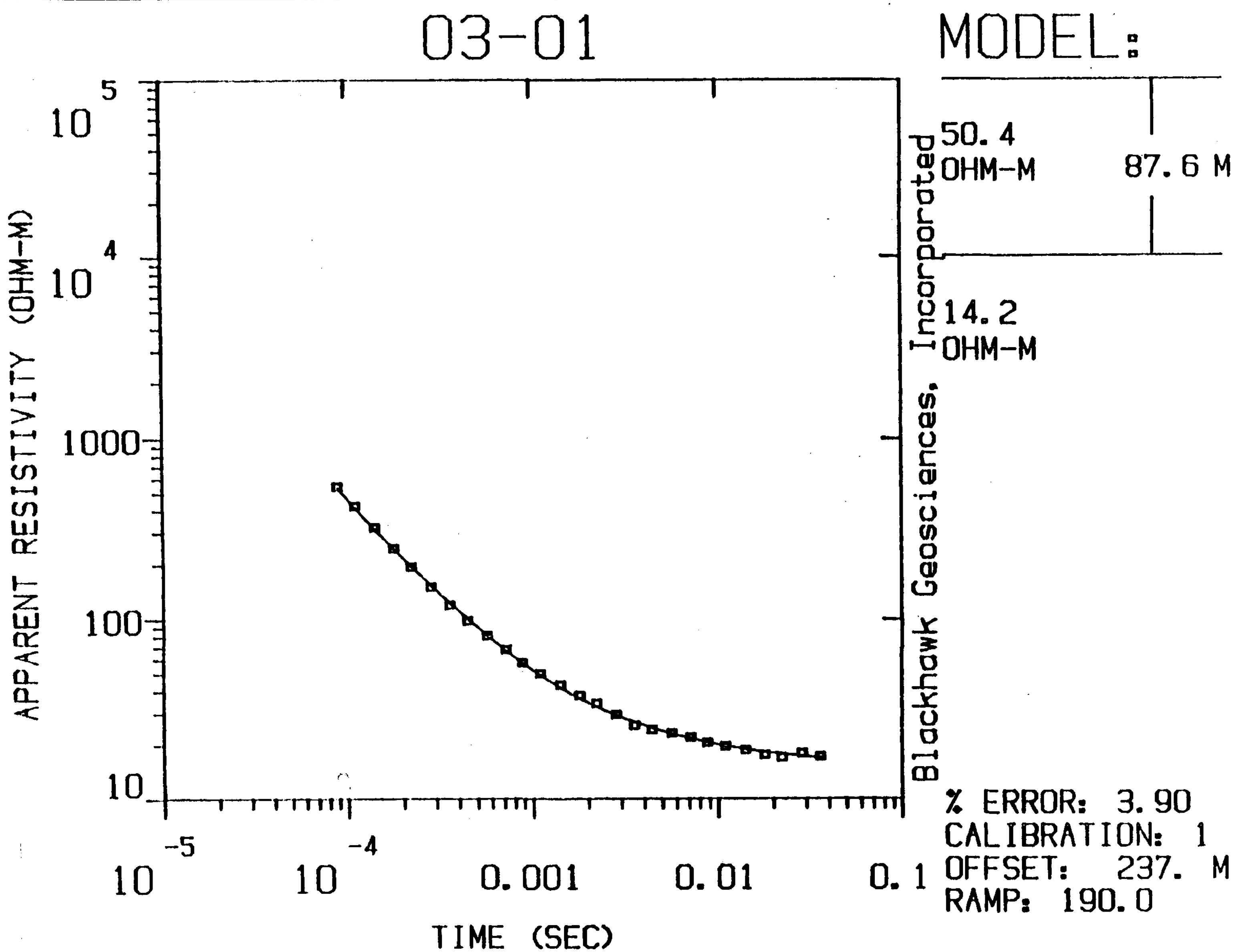


△ BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 2,3,& 14
ROCK SPRINGS, WEKIVA RIVER
AND WEKIVA SPRINGS
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034

Figure 4-4.1

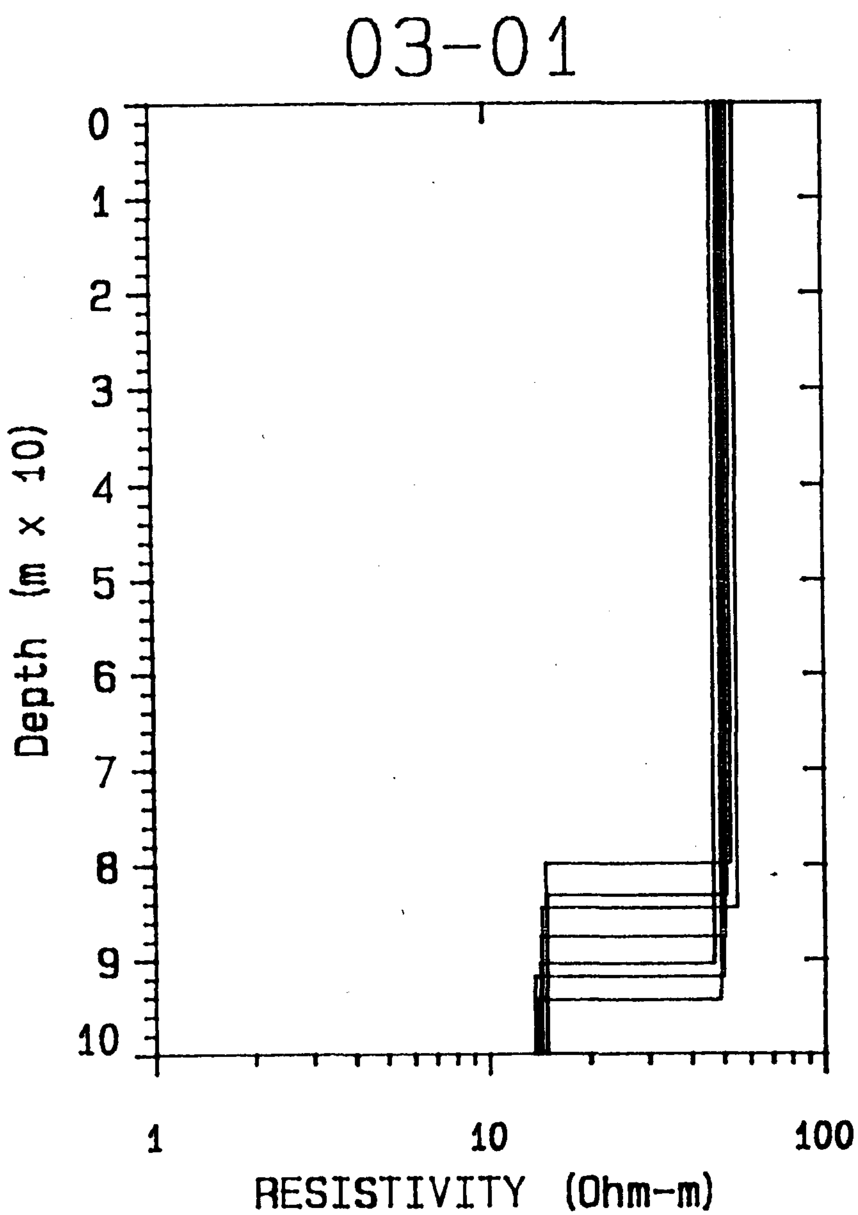


BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

WEKIVA RIVER
SITE 3
St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-4.2**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

WEKIVA RIVER

SITE 3

St. Johns River Water Management District

PROJECT NO: 91034

Figure 4-4.3

03-01

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		12.2	40.0		
50.36	87.6	-75.4	-247.3	1.7	1.7
14.19					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	5.46E+02	5.36E+02	1.955	
2	1.10E-04	4.24E+02	4.14E+02	2.399	
3	1.40E-04	3.21E+02	3.15E+02	1.981	
4	1.77E-04	2.46E+02	2.46E+02	0.182	
5	2.20E-04	1.94E+02	1.97E+02	-1.253	
6	2.80E-04	1.51E+02	1.55E+02	-2.519	
7	3.55E-04	1.20E+02	1.23E+02	-3.069	
8	4.43E-04	9.80E+01	1.01E+02	-2.880	
9	5.64E-04	8.08E+01	8.16E+01	-0.902	
10	7.13E-04	6.75E+01	6.70E+01	0.826	
11	8.81E-04	5.75E+01	5.72E+01	0.541	
12	1.10E-03	4.99E+01	4.91E+01	1.570	
13	1.41E-03	4.32E+01	4.17E+01	3.603	
14	1.80E-03	3.78E+01	3.64E+01	4.045	
15	2.22E-03	3.42E+01	3.28E+01	4.404	
16	2.83E-03	2.94E+01	2.93E+01	0.574	
17	3.55E-03	2.56E+01	2.68E+01	-4.320	
18	4.43E-03	2.43E+01	2.49E+01	-2.452	
19	5.64E-03	2.32E+01	2.30E+01	0.983	
20	7.13E-03	2.20E+01	2.18E+01	1.075	
21	8.81E-03	2.06E+01	2.07E+01	-0.497	
22	1.10E-02	1.96E+01	1.97E+01	-0.497	
23	1.41E-02	1.86E+01	1.89E+01	-1.604	
24	1.80E-02	1.76E+01	1.82E+01	-3.485	
25	2.22E-02	1.70E+01	1.77E+01	-4.029	
26	2.85E-02	1.80E+01	1.72E+01	4.460	
27	3.60E-02	1.72E+01	1.68E+01	2.225	

R: 237. X: 0. Y: 237. DL: 475. REQ: 264. CF: 1.0000

TDHZ ARRAY, 27 DATA POINTS, RAMP: 190.0 MICROSEC, DATA: 03-01

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

WEKIVA RIVER

SITE 3

St. Johns River Management District

PROJECT NO: 91034 **Table 4-4.1**

RMS LOG ERROR: 1.66E-02, ANTILOG YIELDS 3.8953 %

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

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

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	46.620	50.357	54.730
	2	13.612	14.189	14.831
THICK	1	79.931	87.560	94.326
DEPTH	1	79.931	87.560	94.326

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

WEKIVA RIVER

SITE 3

St. Johns River Management District

PROJECT NO: 91034 Table 4-4.1

Summary of Results of TDEM Measurements at Wekiva River (Site 3)

From the TDEM measurements the following information about aquifer characteristics and water quality was derived:

1) The depth of occurrence of highly saline water was interpreted to occur at an elevation of 247 ft below msl. Below that elevation chloride concentrations were inferred to exceed 2,140 mg/l.

2) A resistivity value of 50 ohm-m was measured for the first 287 ft below surface. Since this layer will include the Hawthorn Group and younger sediments, as well as several hundred feet of the Upper Floridan aquifer, no information about chloride concentration was inferred above the interface with highly saline water.

4.5 SIMPSON TRAINING CENTER (SITE 4)

Location and Geoelectric Section

The detailed location of this sounding is shown in Figure 4-5.1. Two soundings were made at this location to assure that the readings were not influenced by cultural interferences. One sounding employed a 1,200 ft by 1,200 ft loop, and one sounding was made with a 500 ft by 500 ft loop. In Figure 4-5.2 the two sounding curves are superimposed. The two curves merge at later times and diverge at earlier time, and this divergence is due to differences in geometric factors caused by different loop sizes. The two data sets were jointly inverted to the three layer geoelectric section shown on Figure 4-5.2.

Geologic Interpretation of Geoelectric Section

The upper layer in the geoelectric section is interpreted to correspond to the Hawthorn Group. Its thickness of 135 ft derived locally at the TDEM stations compares with a regional thickness of 100 ft on the map of Tibbals (1990). The resistivities of the second (466 ohm-m) and third (6.8 ohm-m) layer represent different strata in the carbonate rocks of the Floridan aquifer.

Depth of Occurrence of Highly Saline Water

The lowest resistivity encountered within the effective exploration depth of the measurement is 6.8 ohm-m, and it is first encountered at a depth of 639 ft below surface, or at an elevation of 559 ft below msl. Assuming an average porosity of 25%, the chloride concentration of ground water below that depth is expected to exceed 4,580 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

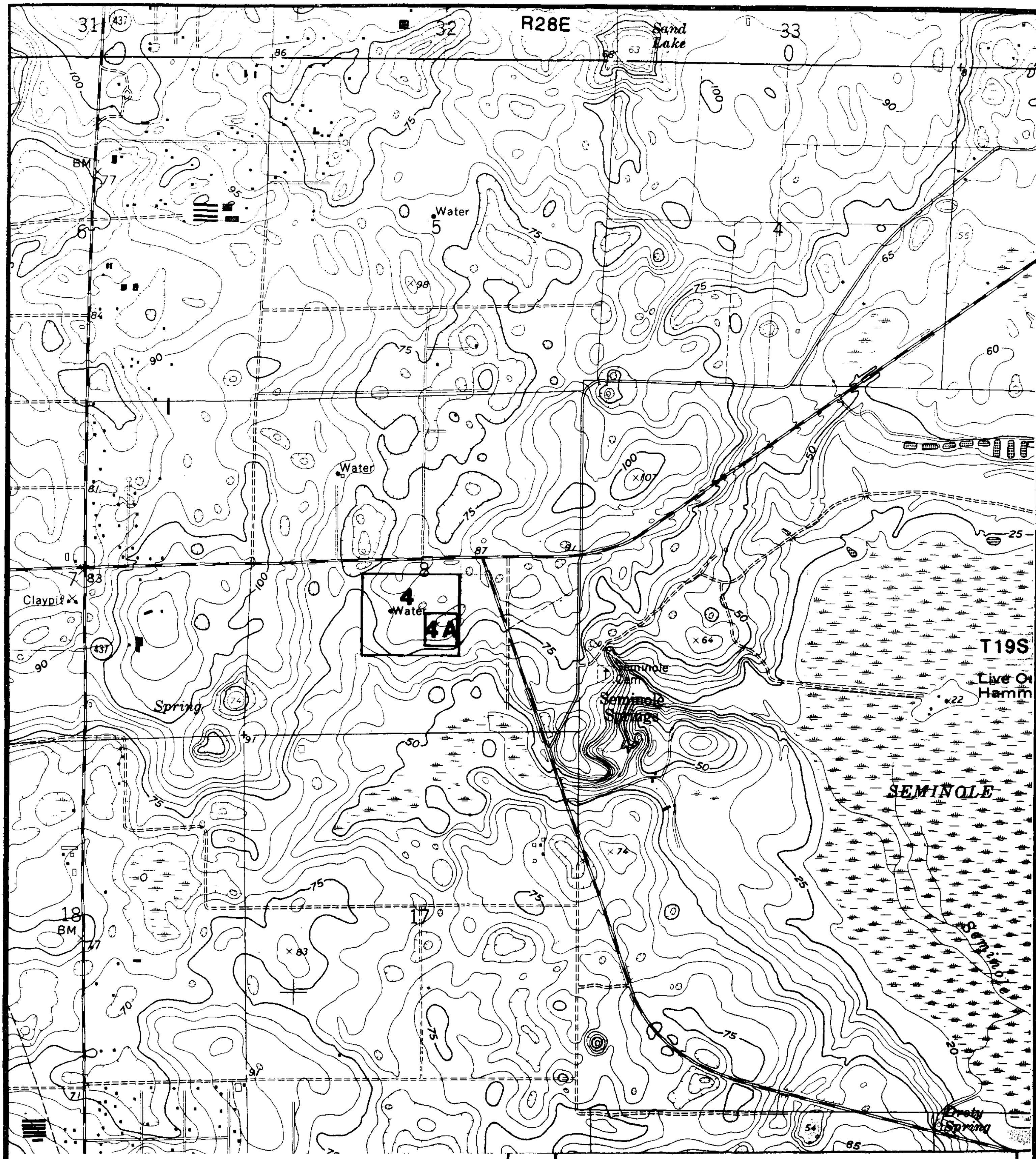
The second layer with a resistivity of 466 ohm-m between 55 ft and 559 ft below msl corresponds to a chloride concentration less than 100 mg/l assuming an average porosity of 25% and validity of the relation displayed on Figure 2-2. The occurrence of the 250 mg/l isochlor is expected to approximately coincide with the elevation of the boundary between the layer of 466 ohm-m and 6.8 ohm-m interpreted at 559 ft below msl. Very likely there will be a transition zone from ground water of low to high chloride concentrations. The thickness of such zones are not measured by TDEM.

Accuracy of Measurement and Interpretation

Figure 4-5.3 shows the computation of equivalence for the TDEM sounding at this site and the inversion table (Table 4-5.1) lists the upper and lower boundary of the parameters of the geoelectric section. The important parameters influencing information inferred about chloride concentration is the resistivity of the second layer. The range of equivalence in the resistivity of that layer is between 190 ohm-m and 2569 ohm-m. That variation, although large in resistivity, does not negate the conclusion about water quality within the interval between elevations of 55 ft and 559 ft below msl. Using an average porosity of 25% and the relation in Figure 2-2, chloride concentrations less than 250 mg/l are predicted for resistivities greater than 80 ohm-m.

Summary of Results of TDEM Measurements at the Simpson Training Center (Site 4)

From the TDEM measurements the following information about aquifer characteristics and water quality was derived:



1	TDEM Sounding

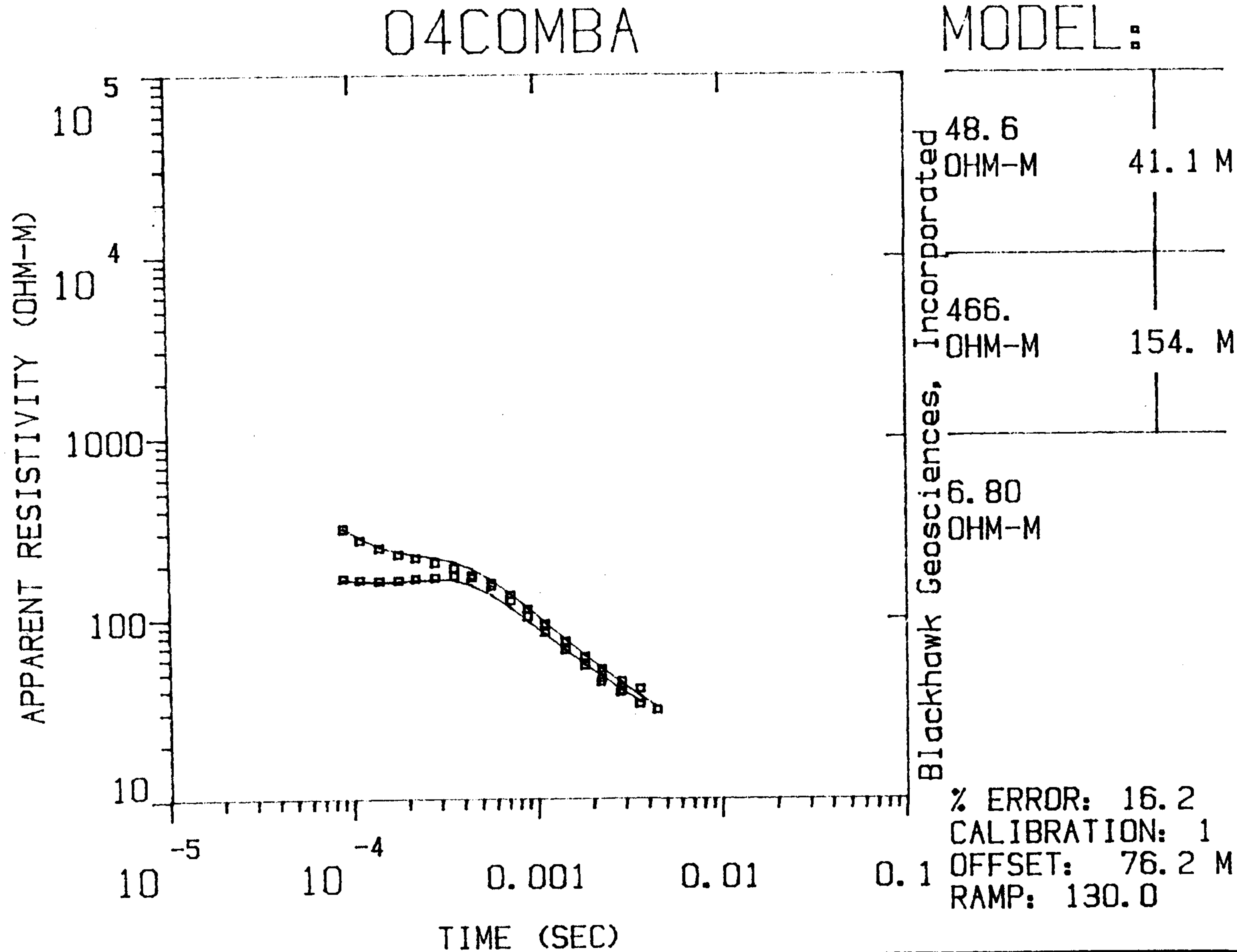
0 2000 4000 Feet

N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 4
SIMPSON TRAINING CENTER
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 **Figure 4-6.1**



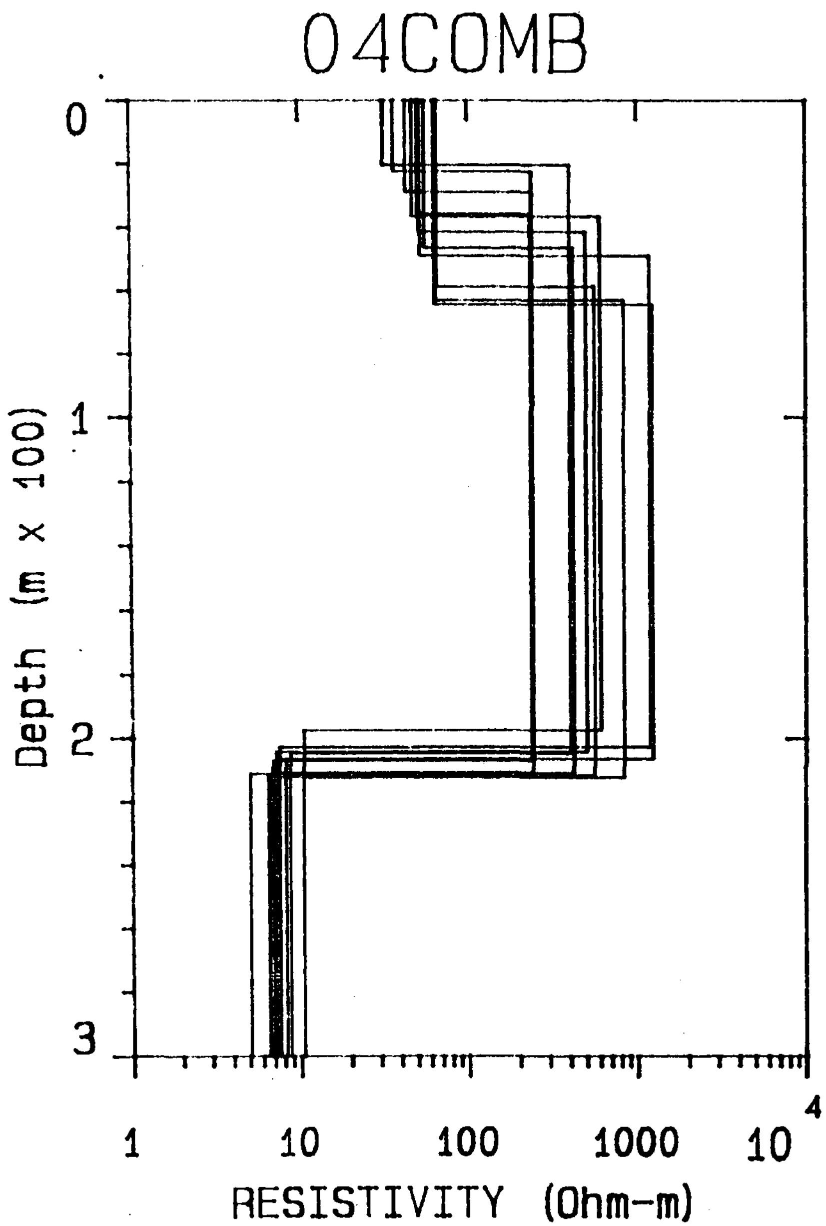
BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

SIMPSON TRAINING CENTER
SITE 4
St. Johns River Water Management District

PROJECT NO: 91034

Figure 4-5.2



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

SIMPSON TRAINING CENTER
SITE 4

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-5.3**

04COMBA

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		24.4	80.0		
48.63	41.1	-16.7	-54.8	0.8	0.8
465.58	153.6	-170.3	-558.8	0.3	1.2
6.80					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.68E+02	1.67E+02	1.006	
2	1.10E-04	1.65E+02	1.62E+02	2.024	
3	1.40E-04	1.63E+02	1.60E+02	1.907	
4	1.77E-04	1.64E+02	1.62E+02	1.429	
5	2.20E-04	1.68E+02	1.65E+02	1.640	
6	2.80E-04	1.70E+02	1.67E+02	1.525	
7	3.55E-04	1.74E+02	1.64E+02	6.096	
8	4.43E-04	1.70E+02	1.53E+02	10.918	
9	5.64E-04	1.58E+02	1.35E+02	16.708	
10	7.13E-04	1.36E+02	1.15E+02	18.213	
11	8.81E-04	1.13E+02	9.74E+01	15.674	
12	1.10E-03	9.30E+01	8.17E+01	13.878	
13	1.41E-03	7.48E+01	6.68E+01	12.112	
14	1.80E-03	6.13E+01	5.54E+01	10.561	
15	2.22E-03	5.23E+01	4.73E+01	10.567	
16	2.85E-03	4.46E+01	3.98E+01	12.096	
17	3.57E-03	4.05E+01	3.43E+01	18.329	
18	8.90E-05	3.19E+02	3.20E+02	-0.388	
19	1.10E-04	2.74E+02	2.80E+02	-2.129	
20	1.40E-04	2.48E+02	2.52E+02	-1.357	
21	1.77E-04	2.29E+02	2.35E+02	-2.859	
22	2.20E-04	2.19E+02	2.26E+02	-3.456	
23	2.80E-04	2.05E+02	2.18E+02	-6.027	
24	3.55E-04	1.92E+02	2.07E+02	-7.117	
25	4.43E-04	1.74E+02	1.89E+02	-8.154	
26	5.64E-04	1.52E+02	1.64E+02	-7.311	
27	7.13E-04	1.25E+02	1.38E+02	-8.860	
28	8.81E-04	1.02E+02	1.15E+02	-11.224	
29	1.10E-03	8.35E+01	9.51E+01	-12.237	

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

SIMPSON TRAINING CENTER

SITE 4

St. Johns River Management District

PROJECT NO: 91034 Table 4-5.1

30	1.41E-03	6.68E+01	7.64E+01	-12.567
31	1.80E-03	5.46E+01	6.25E+01	-12.579
32	2.20E-03	4.41E+01	5.30E+01	-16.790
33	2.22E-03	4.66E+01	5.26E+01	-11.383
34	2.80E-03	3.87E+01	4.41E+01	-12.294
35	2.85E-03	3.94E+01	4.35E+01	-9.456
36	3.55E-03	3.34E+01	3.72E+01	-10.186
37	4.43E-03	3.09E+01	3.20E+01	-3.494

R: 76. X: 0. Y: 76. DL: 152. REQ: 84. CF: 1.0000

R: 185. X: 0. Y: 185. DL: 369. REQ: 0. CF: 1.0000

TDHZ ARRAY, 17 DATA POINTS, RAMP: 130.0 MICROSEC, DATA: 04COMBA

TDHZ ARRAY, 20 DATA POINTS, RAMP: 185.0 MICROSEC, DATA: 04-01A

SIMPSONS TRAINING CENTER LOOP 2

RMS LOG ERROR: 6.51E-02, ANTILOG YIELDS 16.1742 %

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:

"F" MEANS FIXED PARAMETER

	P 1	P 2	P 3	T 1	T 2
P 1	0.98				
P 2	-0.06	0.14			
P 3	0.01	-0.01	0.98		
T 1	-0.04	-0.19	0.01	0.92	
T 2	0.01	0.06	0.00	0.02	0.99

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	35.934	48.635	68.908
	2	189.780	465.575	2568.555
	3	4.054	6.803	11.407
THICK	1	23.827	41.085	77.377
	2	129.939	153.636	174.971
DEPTH	1	23.827	41.085	77.377
	2	185.469	194.721	209.405

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

SIMPSON TRAINING CENTER

SITE 4

St. Johns River Management District

PROJECT NO: 91034 **Table 4-5.1**

1) The depth of occurrence of saline water was interpreted at a depth of 559 ft below msl, and below that depth chloride concentration in excess of 4,580 mg/l are expected.

2) The interface between boundaries of different resistivities at 559 ft below msl was also inferred to approximately represent the 250 mg/l isochlor. Between elevations of 55 ft and 559 ft below msl, chloride concentrations less than 250 mg/l were predicted.

4.6 ROYAL TRAILS (SITE 5)

Location and Geoelectric Section

The detailed location map of this sounding is shown in Figure 4-6.1. The sounding data and the inverted geoelectric section is shown in Figure 4-6.2 and consists of a four layer section. Interference by buried telephone lines along at least two sides of the transmitter loop influenced data quality in earlier time gates, as evidenced by some scatter in the data at times between 10^{-4} sec and 10^{-3} sec. At times greater than 10^{-3} sec little or no scatter in the data is observed.

Geologic Interpretation of Geoelectric Section

The first layer in the geoelectric section is 295 ft thick and has a resistivity of 78 ohm-m. Very likely this layer includes the Hawthorn Group and younger sediments as well as a portion of carbonate rocks of the Upper Floridan aquifer. The second, third, and fourth layers represent different horizons within the carbonate rocks of the Floridan aquifer.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective exploration depth of the measurement is 3.3 ohm-m and it is first encountered at a depth of 1,465 ft below surface, or at an elevation of 1,410 ft below msl. Assuming an average porosity of 25%, the chloride concentration of ground water at that depth is expected to exceed 9,590 mg/l. The geoelectric section shows this layer to be 144 ft thick, and the resistivity to increase below this layer. The most probable interpretation of an increase in resistivity at an elevation of 1,554 ft below msl is a decrease in average porosity of the carbonate rocks.

Depth of Occurrence of 250 mg/l Isochlor

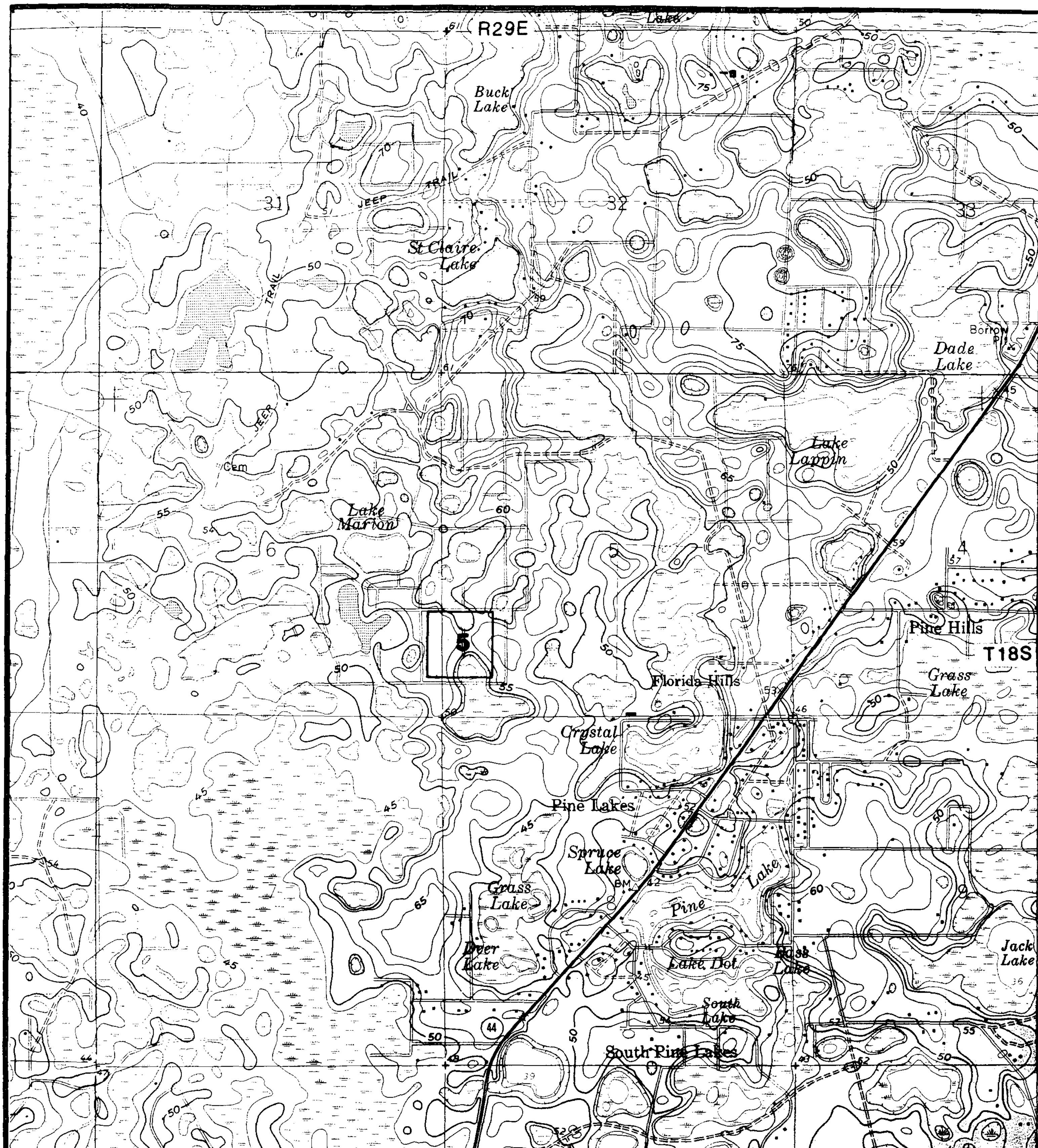
The resistivities of the first two layers is 78 ohm-m and 241 ohm-m. The first layer is 295 ft thick and likely includes the Hawthorn Group and likely 100 ft to 200 ft of the Upper Floridan aquifer. The resistivity of 78 ohm-m may be influenced by some clay layers in the Hawthorn Group which would lower its resistivity. The second layer with a resistivity of 241 ohm-m, occurring between elevations of 240 ft below msl and 1,410 ft below msl, represents the major section of the Floridan aquifer and the water quality in that section is inferred to be below 100 mg/l chloride. The depth of occurrence of the 250 mg/l is expected to coincide with the resistivity boundary (between 241 ohm-m and 3.3 ohm-m) measured at an elevation of 1,410 ft below msl.

Accuracy of Measurement and Interpretation

Figure 4-6.3 shows the evaluation of equivalence for the TDEM sounding at this site, and the inversion table (Table 4-6.1) lists the upper and lower boundary of the parameters of the geoelectric section.

The range of equivalence in determining the depth to the layer of low resistivity (3.3 ohm-m) can be seen on Figure 4-6.3 to be about ±40 m (130 ft) or about 10% of total depth. The upper and lower bound in the resistivity of this layer is between 1.7 ohm-m and 6.4 ohm-m, and although large, does not negate the conclusion that this layer represents carbonate rock of high salinity. At a resistivity of 6.4 ohm-m chloride concentrations greater than 4,800 mg/l are expected.

The equivalence in the resistivity of the second layer, representing the major section of the Floridan aquifer, is between 176 ohm-m and 406 ohm-m. Over this range of resistivities, chloride concentrations less than 250 mg/l



1	TDEM Sounding

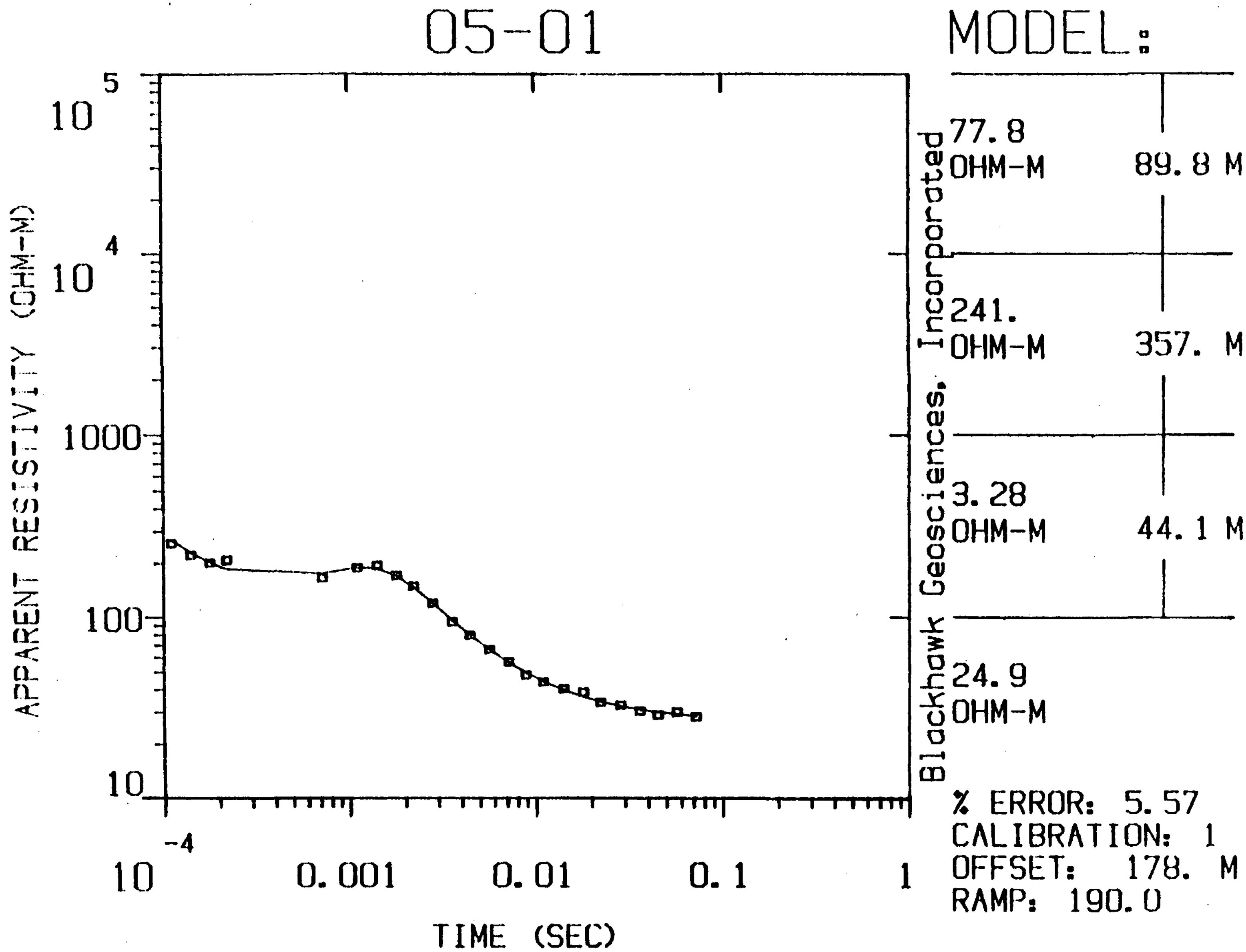
0 2000 4000 Feet

N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 5
ROYAL TRAILS
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 **Figure 4-6.1**

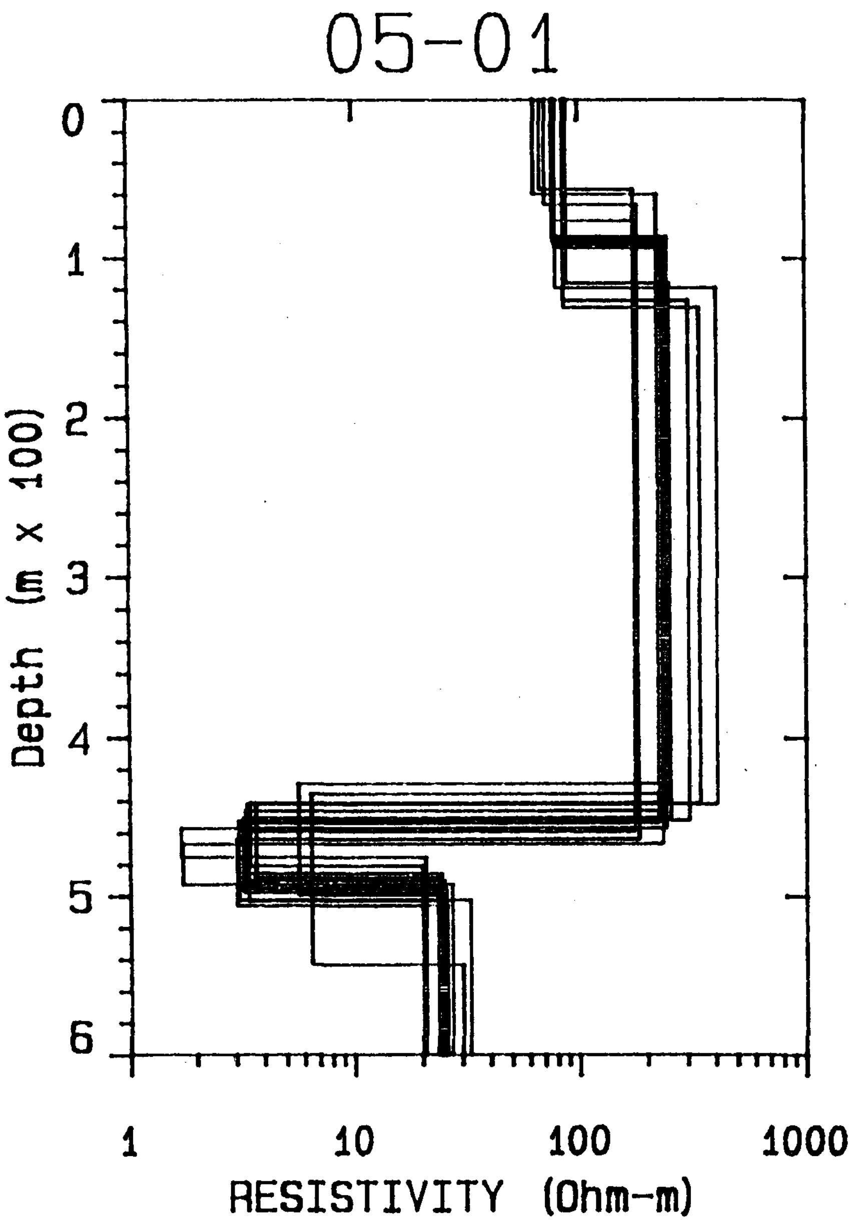


BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

ROYAL TRAILS
SITE 5
St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-6.2**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

ROYAL TRAILS

SITE 5

St. Johns River Water Management District

PROJECT NO: 91034

Figure 4-6.3

05-01

MODEL: 4 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		16.8	55.0		
77.80	89.8	-73.0	-239.7	1.2	1.2
240.60	356.7	-429.7	-1409.9	1.5	2.6
3.28	44.1	-473.8	-1554.4	13.4	16.1
24.95					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	1.10E-04	2.57E+02	2.70E+02	-5.032	
2	1.40E-04	2.21E+02	2.29E+02	-3.767	
3	1.77E-04	2.00E+02	2.02E+02	-1.101	
4	2.20E-04	2.08E+02	1.84E+02	12.578	
5	7.13E-04	1.64E+02	1.74E+02	-5.376	
6	1.10E-03	1.87E+02	1.89E+02	-0.577	
7	1.41E-03	1.93E+02	1.86E+02	3.960	
8	1.78E-03	1.69E+02	1.69E+02	0.051	
9	2.21E-03	1.48E+02	1.46E+02	1.584	
10	2.80E-03	1.19E+02	1.19E+02	-0.069	
11	3.55E-03	9.38E+01	9.61E+01	-2.412	
12	4.43E-03	7.90E+01	7.95E+01	-0.701	
13	5.64E-03	6.57E+01	6.59E+01	-0.185	
14	7.13E-03	5.63E+01	5.60E+01	0.509	
15	8.81E-03	4.78E+01	4.93E+01	-3.143	
16	1.10E-02	4.38E+01	4.41E+01	-0.707	
17	1.41E-02	4.00E+01	3.95E+01	1.196	
18	1.80E-02	3.85E+01	3.63E+01	6.042	
19	2.22E-02	3.37E+01	3.41E+01	-1.088	
20	2.85E-02	3.25E+01	3.22E+01	1.094	
21	3.60E-02	3.02E+01	3.08E+01	-1.930	
22	4.49E-02	2.88E+01	2.98E+01	-3.442	
23	5.70E-02	2.99E+01	2.89E+01	3.225	
24	7.19E-02	2.81E+01	2.83E+01	-0.824	

R: 178. X: 0. Y: 178. DL: 356. REQ: 198. CF: 1.0000

TDHZ ARRAY, 24 DATA POINTS, RAMP: 190.0 MICROSEC, DATA: 05-01

ROYAL TRAILS

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

ROYAL TRAILS

SITE 5

St. Johns River Management District

PROJECT NO: 91034 **Table 4-8.1**

RMS LOG ERROR: 2.36E-02, ANTILOG YIELDS 5.5747 %

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:

"F" MEANS FIXED PARAMETER

P 1	0.93						
P 2	-0.03	0.36					
P 3	0.01	-0.02	0.49				
P 4	-0.01	0.04	0.06	0.74			
T 1	-0.15	-0.35	0.04	-0.02	0.50		
T 2	0.04	0.12	0.04	-0.01	0.13	0.95	
T 3	0.00	0.00	-0.44	-0.12	-0.01	0.02	0.41
	P 1	P 2	P 3	P 4	T 1	T 2	T 3

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	63.813	77.801	88.385
	2	175.784	240.598	406.399
	3	1.700	3.283	6.413
	4	20.082	24.946	32.670
THICK	1	56.979	89.810	131.813
	2	310.000	356.679	402.312
	3	18.314	44.064	107.642
DEPTH	1	56.979	89.810	131.813
	2	429.396	446.490	467.501
	3	475.793	490.554	543.355

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

ROYAL TRAILS

SITE 5

St. Johns River Management District

PROJECT NO: 91034 Table 4-6.1

are predicted assuming 25% porosity and validity of the relation shown on Figure 2-2.

Summary of Results of TDEM Measurements at Royal Trails (Site 5)

From the TDEM measurements the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted at an elevation of 1,410 ft below msl, and below that depth chloride concentrations in excess of 9,590 mg/l are inferred.

2) This interface at 1,410 ft below msl is also inferred to be the elevation of occurrence of the 250 mg/l isochlor. The main aquifer section between elevations of 240 ft and 1,410 ft below msl is expected to contain ground water with chloride concentrations less than 250 mg/l chloride.

4.7 ORMOND BEACH - WEST WELL FIELD (SITE 6)

Location and Geoelectric Section

The detailed location map of this sounding is shown in Figure 4-7.1. The TDEM data and the inverted geoelectric section is shown in Figure 4-7.2 and consists of a three layer section.

Geologic Interpretation of Geoelectric Section

Well MW-2 is located approximately 1.5 to 2 miles west of sounding 6, and in Figure 4-7.3 the lithologic drilling log and two geophysical logs run in the well are compared with the geoelectric section derived from the TDEM sounding. The comparison provides a key for inferring geology from the geoelectric section assuming that the geology can be interpolated over a distance of about two miles:

1) The upper layer of 39 ohm-m and 76 ft thick corresponds to sands and clays of surficial sediments overlaying the carbonate rocks.

2) The resistance log in the borehole shows no change in trend below the casing from about 80 ft to the depth of completion of the hole (290 ft). This is consistent with the geoelectric section derived from TDEM which indicates a resistivity of 98 ohm-m from a depth of about 76 ft to 1,122 ft below surface.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective depth of the measurement is 2.3 ohm-m, and it is first encountered at a depth of 1,122 ft below surface or at an elevation of 1,087 ft below msl. Assuming an average porosity of 25% the chloride concentration at that depth is expected to exceed 10,000 mg/l.

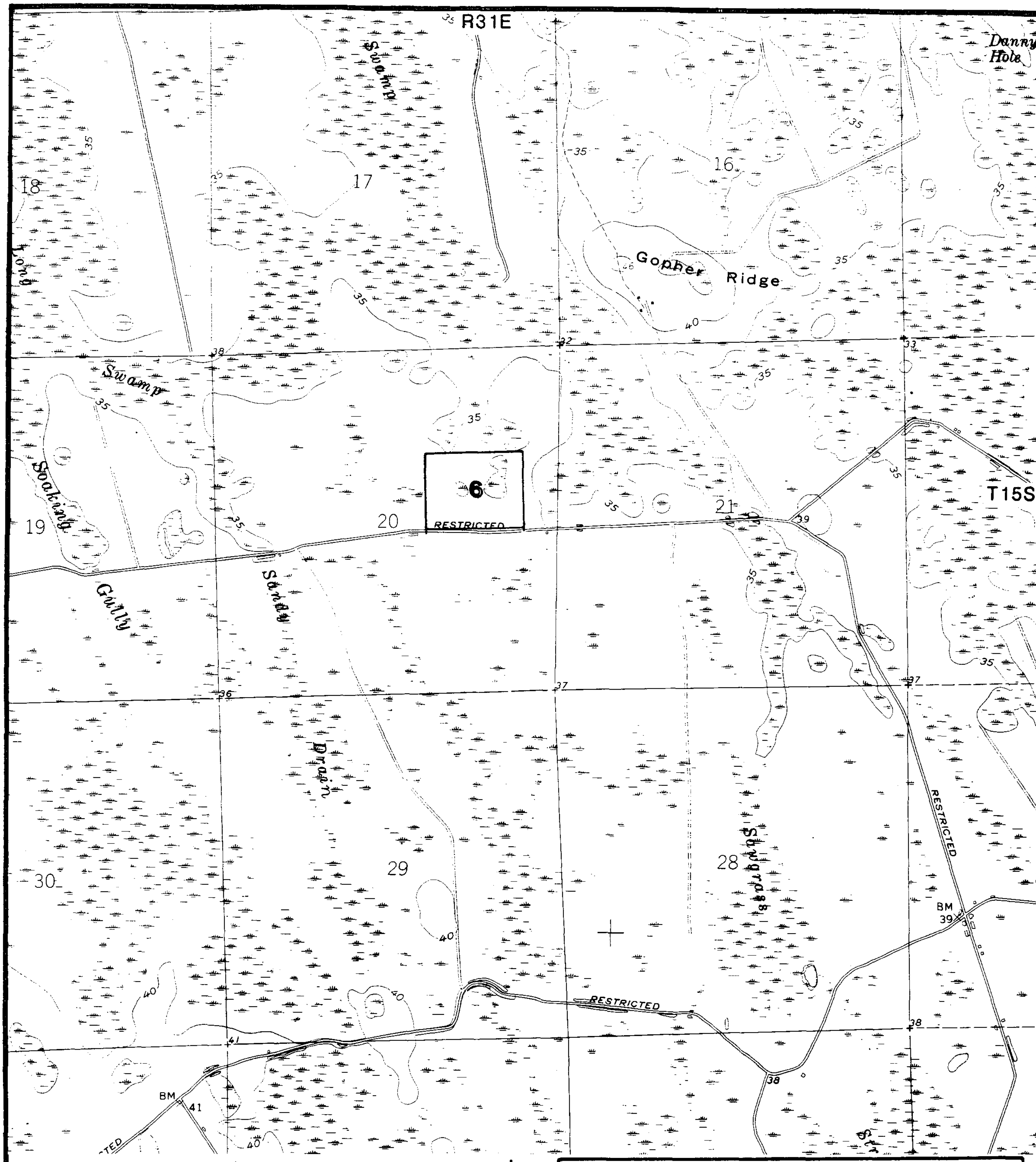
Depth of Occurrence of 250 mg/l Isochlor

The resistivity of the carbonate rocks of the Floridan aquifer below the surficial sediments interpreted from the TDEM data is 98 ohm-m. The resistivity of this layer characterizes the carbonate rocks between an elevation of about 41 ft below msl to 1,087 ft below msl. Assuming an average porosity of 25% a chloride concentration less than 250 mg/l is inferred from the geoelectric section. This is consistent with information published by Tibbals (1990) which shows the upper Floridan to contain less than 250 ppm chloride at this location. The depth of occurrence of the 250 ppm chloride is expected to coincide with the resistivity boundary mapped at an elevation of 1,087 ft below msl.

Accuracy of Measurement and Interpretation

Figure 4-7.4 shows the evaluation of equivalence of the TDEM sounding at this site and the inversion table (Table 4-7.1) lists the upper and lower bounds of the parameters of the geoelectric section. The range of equivalence indicated for the depth of the highly saline layer is less than 2% of total depth, or about ± 20 ft. The resistivity range of the second layer, characteristic of the major section of the Floridan aquifer, may vary between 92 ohm-m and 109 ohm-m. Variation within this range does not negate the conclusion that the chloride concentration is below 250 mg/l.

Very likely a transition zone where the chloride concentration increases gradually from less than 250 mg/l to in excess of 10,000 mg/l will occur above the interface determined at an elevation of 1,087 ft below msl. Such a transition zone is not mapped with TDEM and may be as large as 100 ft to 200 ft.



1 TDEM Sounding

0 2000 4000 Feet

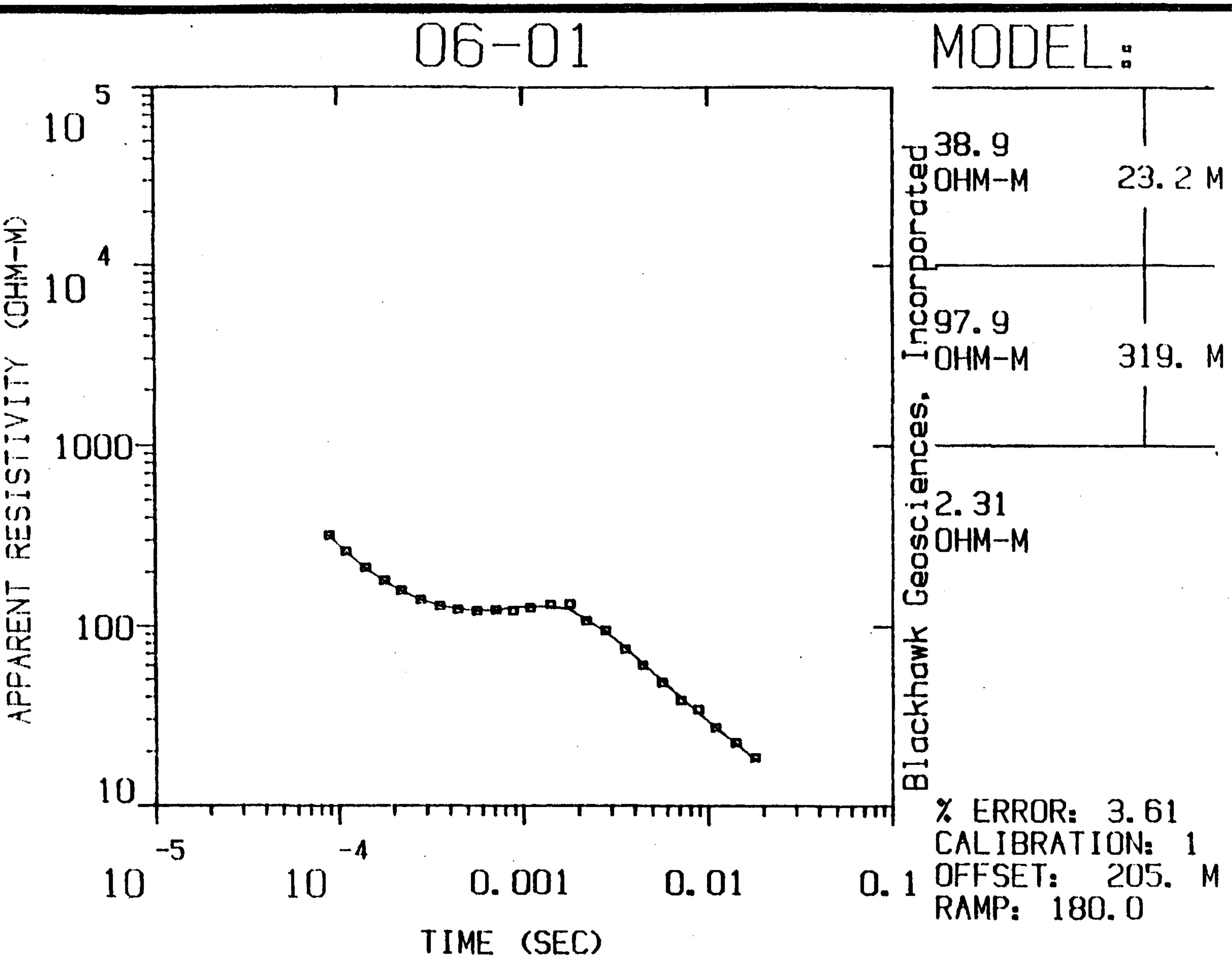
N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 6
ORMOND BEACH
WESTERN WELL FIELD
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034

Figure 4-7.1



BLACKHAWK GEOSCIENCES, INC.

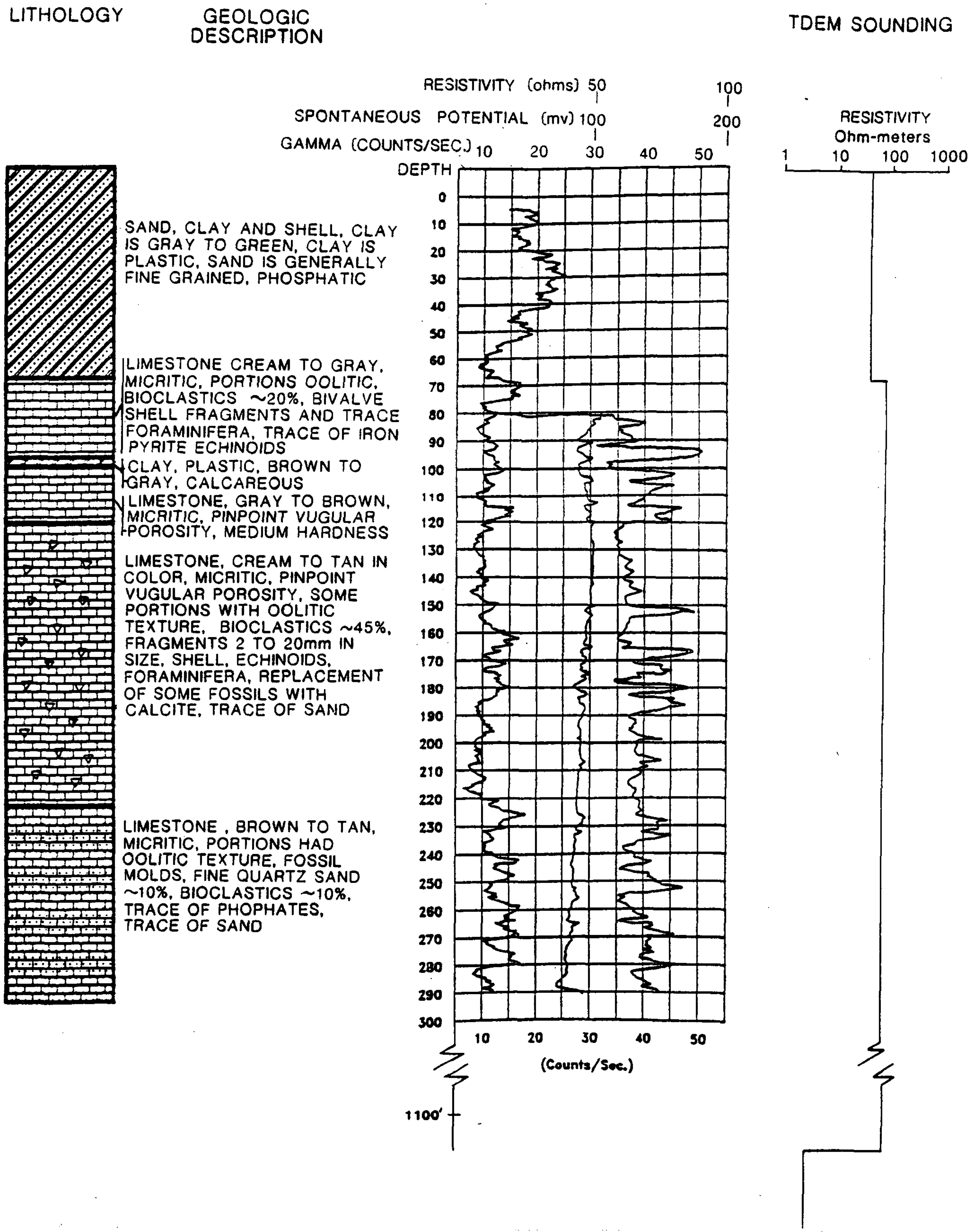
MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

ORMOND BEACH-WEST WELL FIELD

SITE 6

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-7.2**

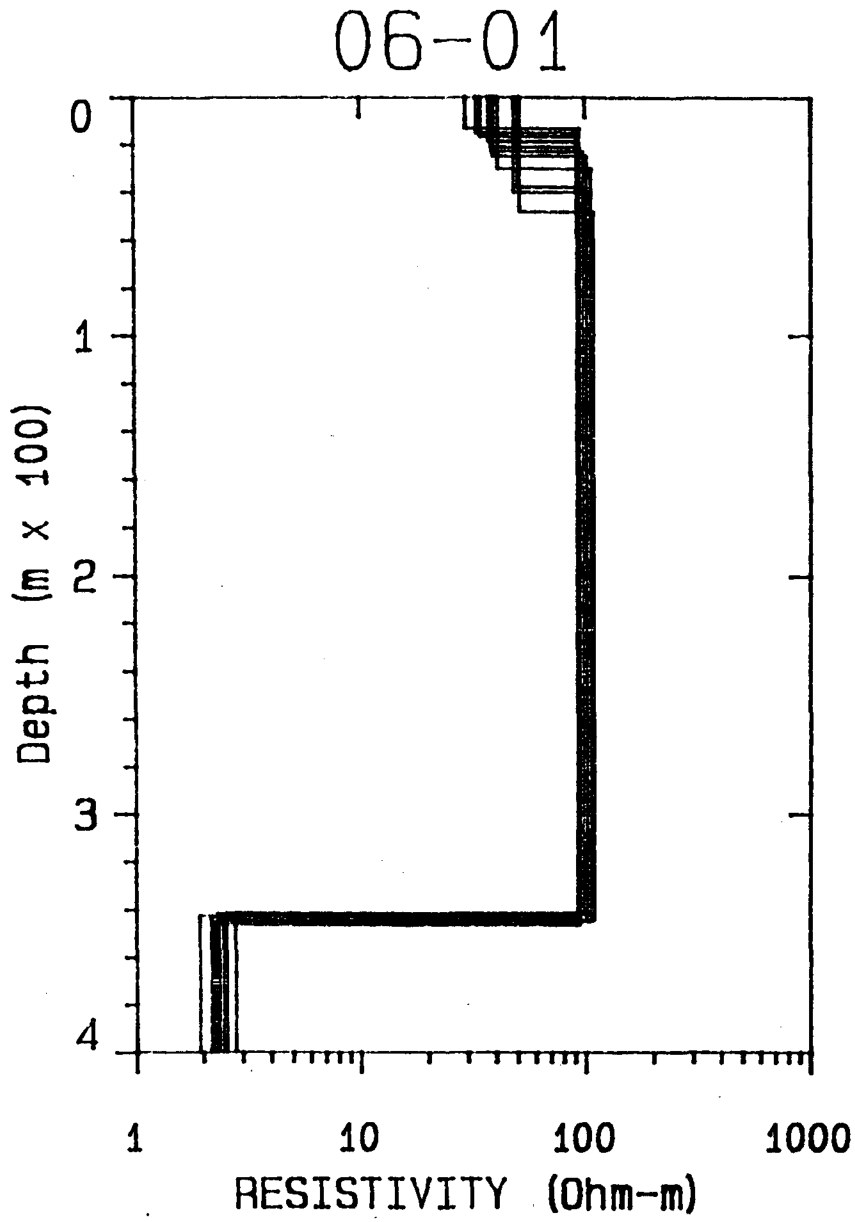


BLACKHAWK GEOSCIENCES, INC.

ORMOND BEACH WEST WELLFIELD
TDEM SOUNDING-DRILLHOLE COMPARISON

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-7.3**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

ORMOND BEACH-WEST WELL FIELD

SITE 6

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-7.4**

MODEL: 3 LAYERS

RESISTIVITY	THICKNESS	ELEVATION		CONDUCTANCE (S)	
(OHM-M)	(M)	(M)	(FEET)	LAYER	TOTAL
		10.7	35.0		
38.89	23.2	-12.5	-41.2	0.6	0.6
97.89	318.7	-331.3	-1086.8	3.3	3.9
2.31					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	3.20E+02	3.19E+02	0.269	
2	1.10E-04	2.61E+02	2.58E+02	0.868	
3	1.40E-04	2.12E+02	2.10E+02	0.709	
4	1.77E-04	1.79E+02	1.78E+02	0.712	
5	2.20E-04	1.58E+02	1.57E+02	0.365	
6	2.80E-04	1.40E+02	1.40E+02	-0.209	
7	3.55E-04	1.29E+02	1.30E+02	-0.439	
8	4.43E-04	1.23E+02	1.25E+02	-1.012	
9	5.64E-04	1.21E+02	1.21E+02	0.012	
10	7.13E-04	1.23E+02	1.22E+02	0.748	
11	8.81E-04	1.22E+02	1.27E+02	-4.306	
12	1.10E-03	1.26E+02	1.28E+02	-1.285	
13	1.41E-03	1.32E+02	1.28E+02	2.891	
14	1.80E-03	1.33E+02	1.24E+02	7.118	
15	2.20E-03	1.07E+02	1.08E+02	-1.126	
16	2.80E-03	9.40E+01	9.26E+01	1.465	
17	3.55E-03	7.37E+01	7.57E+01	-2.735	
18	4.43E-03	6.00E+01	6.11E+01	-1.820	
19	5.64E-03	4.81E+01	4.91E+01	-1.957	
20	7.13E-03	3.83E+01	3.98E+01	-3.607	
21	8.81E-03	3.41E+01	3.27E+01	4.353	
22	1.10E-02	2.70E+01	2.71E+01	-0.430	
23	1.41E-02	2.23E+01	2.20E+01	1.035	
24	1.80E-02	1.84E+01	1.81E+01	1.627	

R: 205. X: 0. Y: 205. DL: 409. REQ: 228. CF: 1.0000

CLHZ ARRAY, 24 DATA POINTS, RAMP: 180.0 MICROSEC, DATA: 06-01

ORMOND BEACH WEST WELL FIELD

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

ORMOND BEACH-WEST WELL FIELD

SITE 6

St. Johns River Management District

PROJECT NO: 91034 Table 4-7.1

RMS LOG ERROR: 1.54E-02, ANTILOG YIELDS 3.6093 %

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:

"F" MEANS FIXED PARAMETER

P 1	1.00				
P 2	0.00	1.00			
P 3	0.00	0.00	1.00		
T 1	0.00	0.00	0.00	0.99	
T 2	0.00	0.00	0.00	0.00	1.00
	P 1	P 2	P 3	T 1	T 2

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	29.528	38.891	51.365
	2	92.173	97.886	109.125
	3	1.928	2.313	2.776
THICK	1	13.426	23.217	48.435
	2	296.246	318.721	333.004
DEPTH	1	13.426	23.217	48.435
	2	341.472	341.938	346.430

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

ORMOND BEACH-WEST WELL FIELD

SITE 6

St. Johns River Management District

PROJECT NO: 91034 Table 4-7.1

Summary of Results of TDEM Measurements at Ormond Beach - West Well Field (Site 6)

From the TDEM measurements the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted at an elevation of 1,087 ft below msl, and below that depth chloride concentrations in excess of 10,000 mg/l chloride are expected.

2) The interface at 1,087 ft below msl is also inferred as the elevation of occurrence of the 250 mg/l isochlor. The main aquifer section between elevations of 41 ft below msl and 1,087 ft below msl is expected to contain ground water with chloride concentrations less than 250 mg/l.

4.8 ASTRONAUT HIGH SCHOOL (SITE 7)

Location and Geoelectric Section

The detailed location map of this sounding is shown in Figure 4-8.1. The TDEM data and the inverted geoelectric section is shown in Figure 4-8.2 and consists of a two layer section.

Comparison of Resistivity Log in a Nearby Well with TDEM Derived Geoelectric Section

In Figure 4-8.3 the resistivity log in a nearby well is compared with the geoelectric section derived from TDEM surveys. The two data sets agree about the depth of occurrence (181 ft below surface) of a low resistivity layer in the section, but are in disagreement about absolute values. Above this depth the resistivity varies greatly in the resistivity log. The upper layer of about 30 ohm-m measured with the TDEM likely represents surficial sediments, the Hawthorn Group, and portions of the upper carbonate rocks of the Floridan aquifer. It is an average resistivity of all the various sand and clay layers encountered within the upper 181 ft.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective depth of the measurement is 2.5 ohm-m, and it is first encountered at a depth of 181 ft below surface or at an elevation of 156 ft below msl. Assuming an average porosity of 25% the chloride concentration below that depth is expected to exceed 10,000 mg/l.

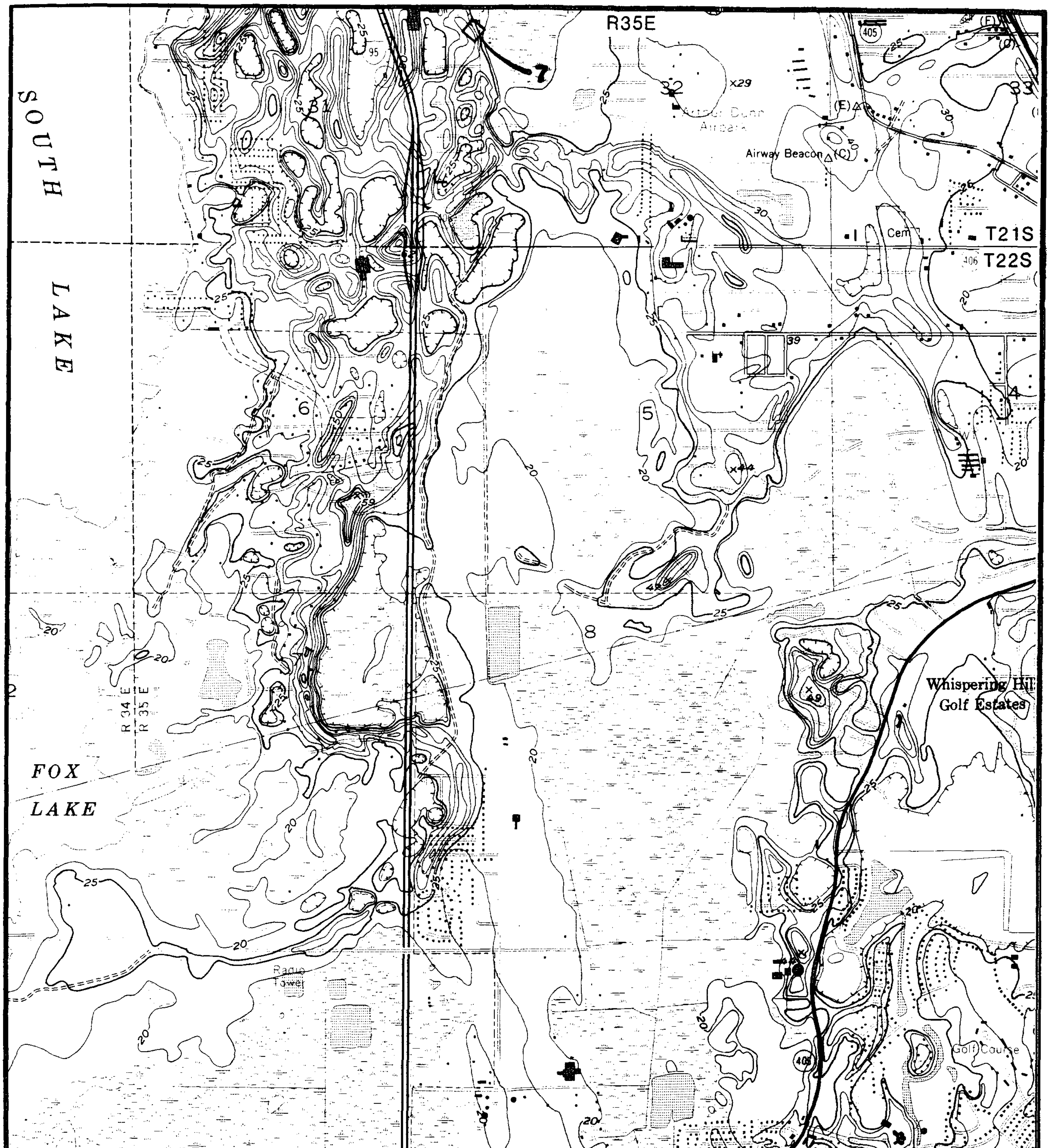
Depth of Occurrence of 250 mg/l Isochlor

The resistivity of the upper 181 ft likely include portions of the carbonate rocks below the Hawthorn Group. However, since the upper 181 ft includes the Hawthorn Group and younger sediments, the resistivity of 30 ohm-m may be influenced by clay layers. Chloride concentration can, therefore, not be inferred for this layer.

Accuracy of Measurement and Interpretation

Figure 4-8.4 shows the evaluation of equivalence of the TDEM sounding at this site, and the inversion table (Table 4-8.1) lists the upper and lower bounds of the parameters of the geoelectric section. The range of equivalence of all parameters is relatively small. The error of measurement in determining the elevation of the interface with saline water is expected to be ± 5% of total depth, or about ± 10 ft.

The range of resistivity of the upper layer may vary between 27 ohm-m and 32 ohm-m. Since clay layers in the Hawthorn Group and younger sediments likely influence this range of resistivity measured, no conclusions about chloride concentration can be drawn.



1	TDEM Sounding

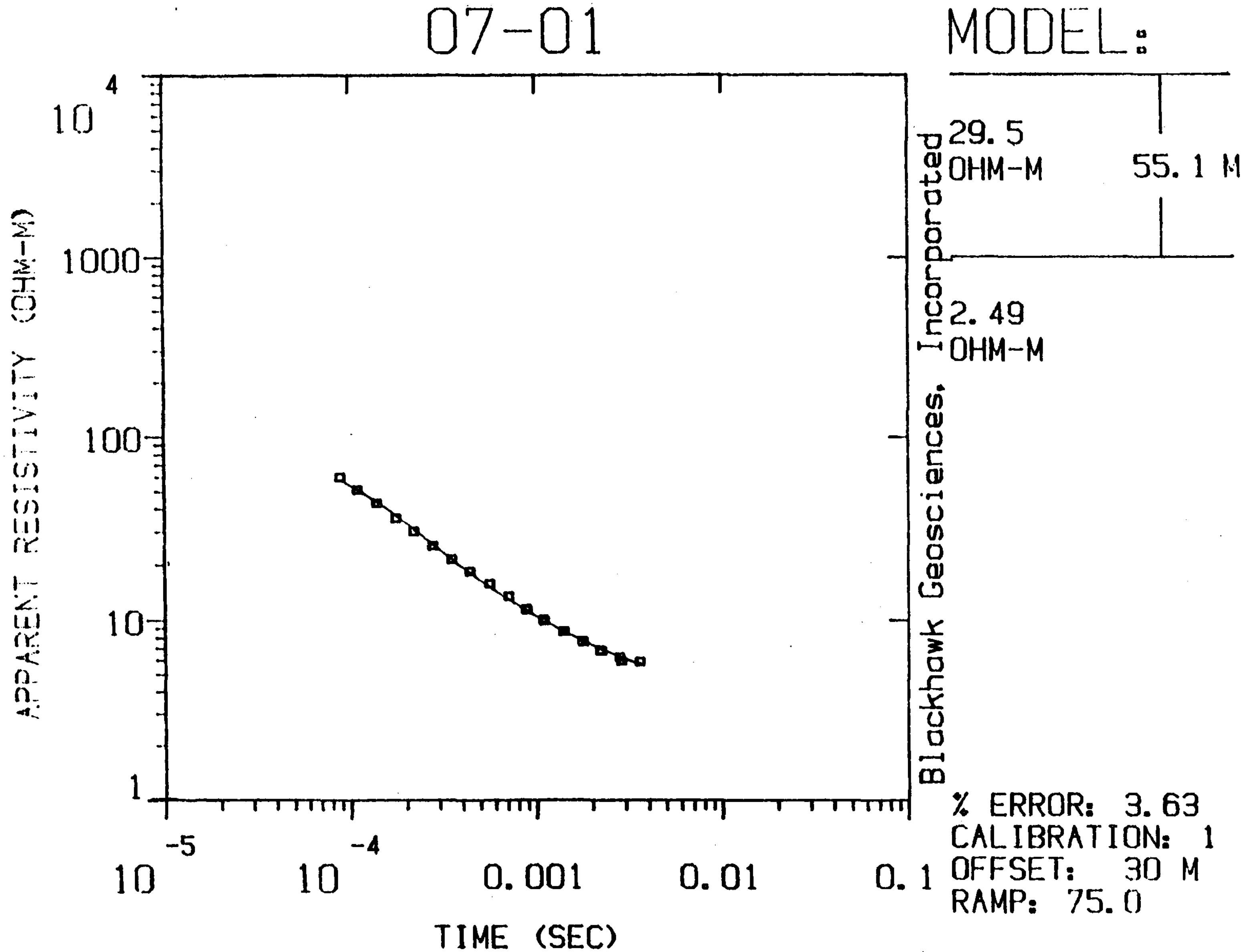
0 2000 4000 Feet

N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 7
ASTRONAUT HIGH SCHOOL
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 **Figure 4-8.1**



BLACKHAWK GEOSCIENCES, INC.

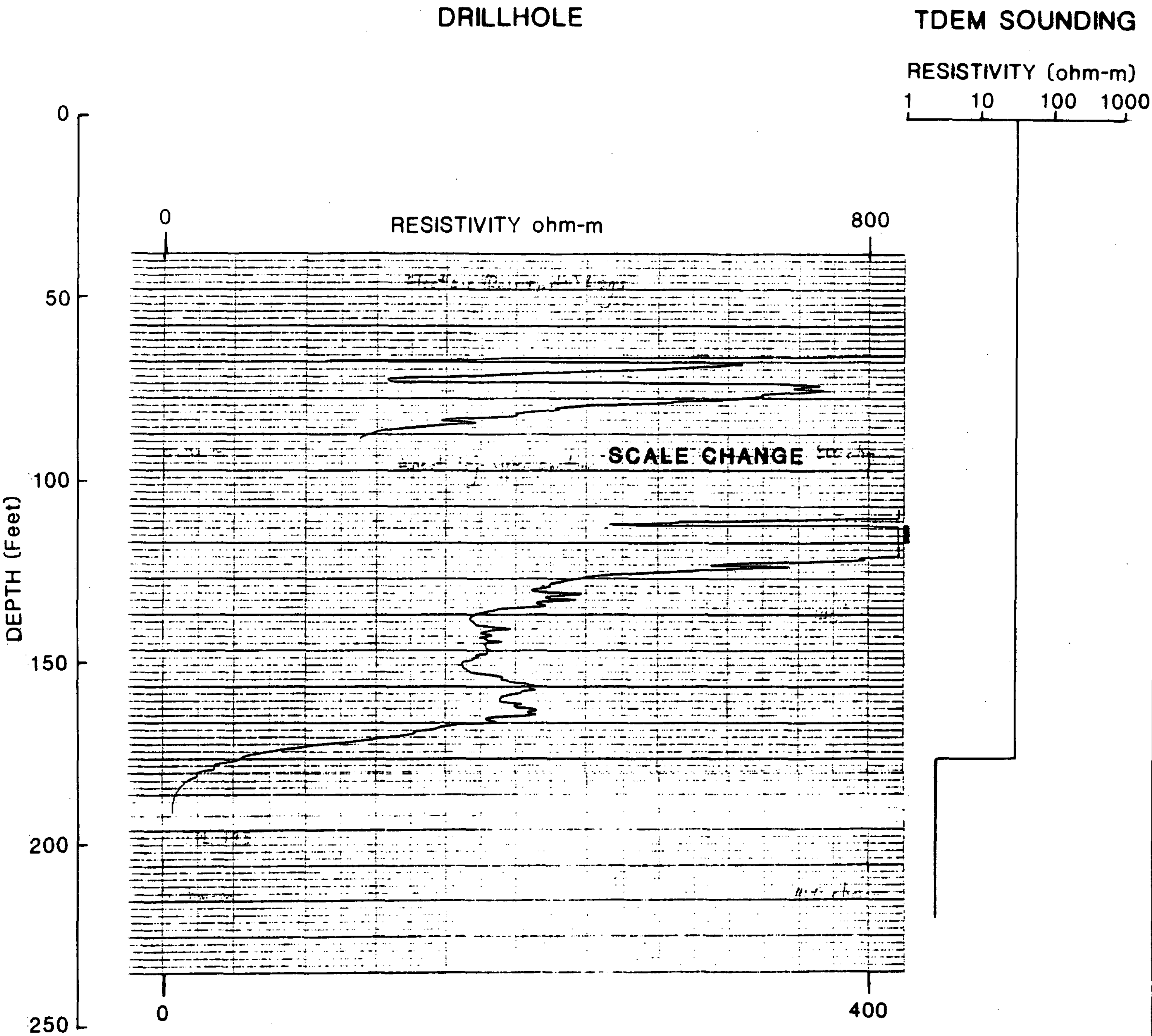
MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

ASTRONAUT HIGH SCHOOL

SITE 7

St. Johns River Water Management District

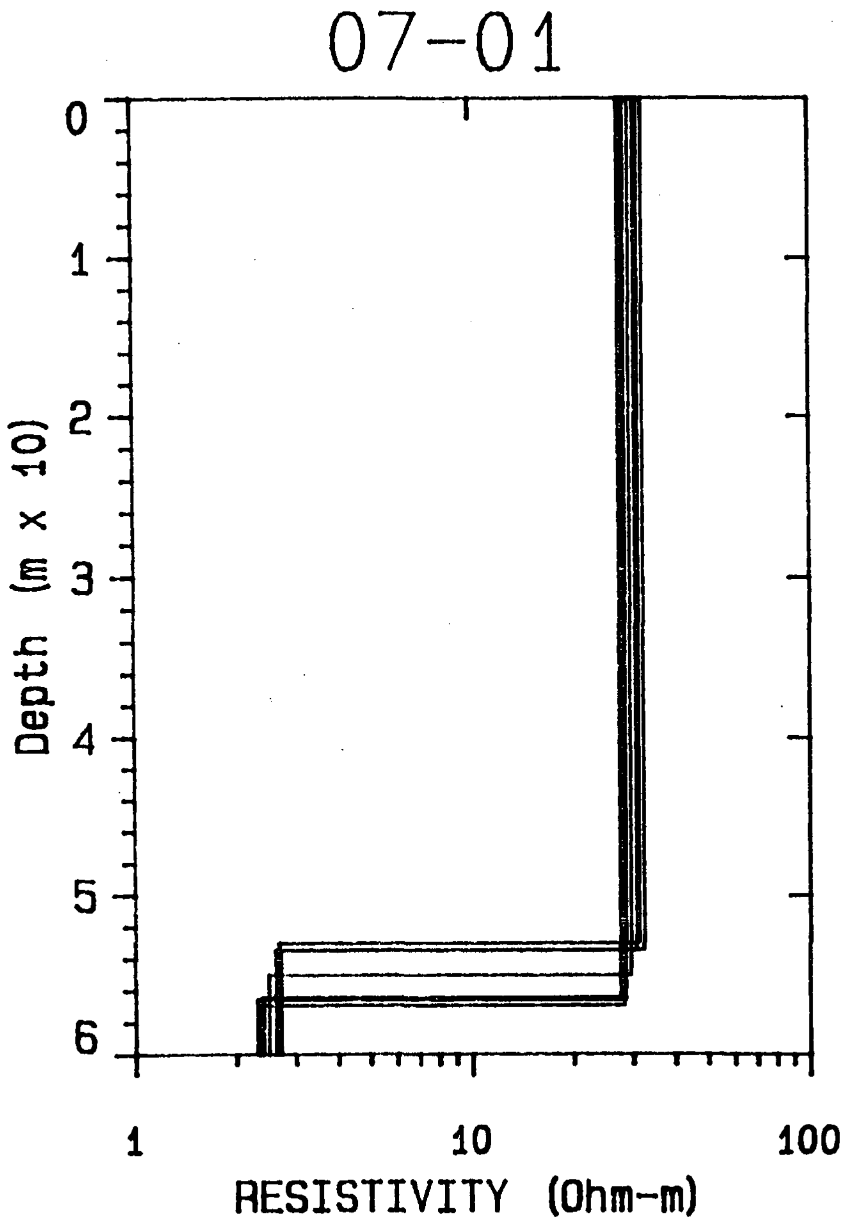
PROJECT NO: 91034 **Figure 4-8.2**



BLACKHAWK GEOSCIENCES, INC.

ASTRONAUT HIGH SCHOOL
TDEM SOUNDING-DRILLHOLE
COMPAIRSON
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 Figure 4-6.3



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

ASTRONAUT HIGH SCHOOL

SITE 7

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-8.4**

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		7.6	25.0		
29.53	55.1	-47.5	-155.7	1.9	1.9
2.49					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	5.98E+01	5.78E+01	3.300	
2	1.10E-04	5.09E+01	5.12E+01	-0.497	
3	1.40E-04	4.27E+01	4.36E+01	-2.021	
4	1.77E-04	3.54E+01	3.67E+01	-3.639	
5	2.20E-04	3.01E+01	3.10E+01	-2.869	
6	2.80E-04	2.51E+01	2.56E+01	-1.818	
7	3.55E-04	2.13E+01	2.13E+01	-0.112	
8	4.43E-04	1.83E+01	1.80E+01	1.604	
9	5.64E-04	1.58E+01	1.51E+01	4.104	
10	7.13E-04	1.35E+01	1.29E+01	4.285	
11	8.81E-04	1.15E+01	1.13E+01	1.631	
12	8.90E-04	1.14E+01	1.12E+01	1.440	
13	1.10E-03	1.00E+01	9.90E+00	1.211	
14	1.10E-03	9.88E+00	9.88E+00	-0.050	
15	1.40E-03	8.60E+00	8.64E+00	-0.495	
16	1.41E-03	8.64E+00	8.60E+00	0.451	
17	1.77E-03	7.63E+00	7.66E+00	-0.454	
18	1.80E-03	7.53E+00	7.61E+00	-1.053	
19	2.20E-03	6.75E+00	6.91E+00	-2.295	
20	2.22E-03	6.73E+00	6.88E+00	-2.151	
21	2.80E-03	6.20E+00	6.23E+00	-0.426	
22	2.85E-03	5.90E+00	6.18E+00	-4.485	
23	3.60E-03	5.86E+00	5.64E+00	3.797	

R: 30. X: 0. Y: 30. DL: 60. REQ: 33. CF: 1.0000

CLHZ ARRAY, 23 DATA POINTS, RAMP: 75.0 MICROSEC, DATA: 07-01

ASTRONAUT HIGH SCHOOL

RMS LOG ERROR: 1.55E-02, ANTILOG YIELDS 3.6305 %

LATE TIME PARAMETERS

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

ASTRONAUT HIGH SCHOOL

SITE 7

St. Johns River Management District

PROJECT NO: 91034 **Table 4-8.1**

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:

"F" MEANS FIXED PARAMETER

P 1	0.99		
P 2	-0.01	0.99	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	27.462	29.528	32.165
	2	2.305	2.490	2.704
THICK	1	53.037	55.074	56.953
DEPTH	1	53.037	55.074	56.953

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

ASTRONAUT HIGH SCHOOL

SITE 7

St. Johns River Management District

PROJECT NO: 91034 Table 4-8.1

Summary of Results of TDEM Measurements at Astronaut High School (Site 7)

From the TDEM measurements the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted to occur at an elevation of 156 ft below msl, and below that depth chloride concentrations in excess of 10,000 mg/l chloride are expected.

2) Because no distinction could be made between the resistivity values of the Hawthorn Group, surficial sediments, and the carbonate rocks of the Upper Floridan, no information about chloride concentration could be inferred above the highly saline water interface.

4.9 NORTH BREVARD WASTE WATER TREATMENT PLANT (SITE 8)

Location and Geoelectric Section

The detailed location map of this sounding is shown in Figure 4-9.1. The TDEM data and the inverted geoelectric section is shown in Figure 4-9.2 and consists of a two layer section.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective depth of the measurement is 1.6 ohm-m, and it is first encountered at a depth of 183 ft below surface or at an elevation of 168 ft below msl. Assuming an average porosity of 25% the chloride concentration below that depth is expected to exceed 10,000 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

The resistivity of the upper 183 ft likely include portions of the carbonate rocks below the Hawthorn Group and younger sediments. Since the resistivity of 36 ohm-m may have been influenced by clay layers, no information about chloride concentration can be inferred for this upper layer.

Accuracy of Measurement and Interpretation

Figure 4-9.3 shows the evaluation of equivalence of the TDEM sounding at this site, and the inversion table (Table 4-9.1) lists the upper and lower bounds of the parameters of the geoelectric section. The range of equivalence of all parameters is relatively small. The error of measurement in determining the elevation of the interface with saline water is expected to be ± 5% of total depth, or about ± 10 ft.

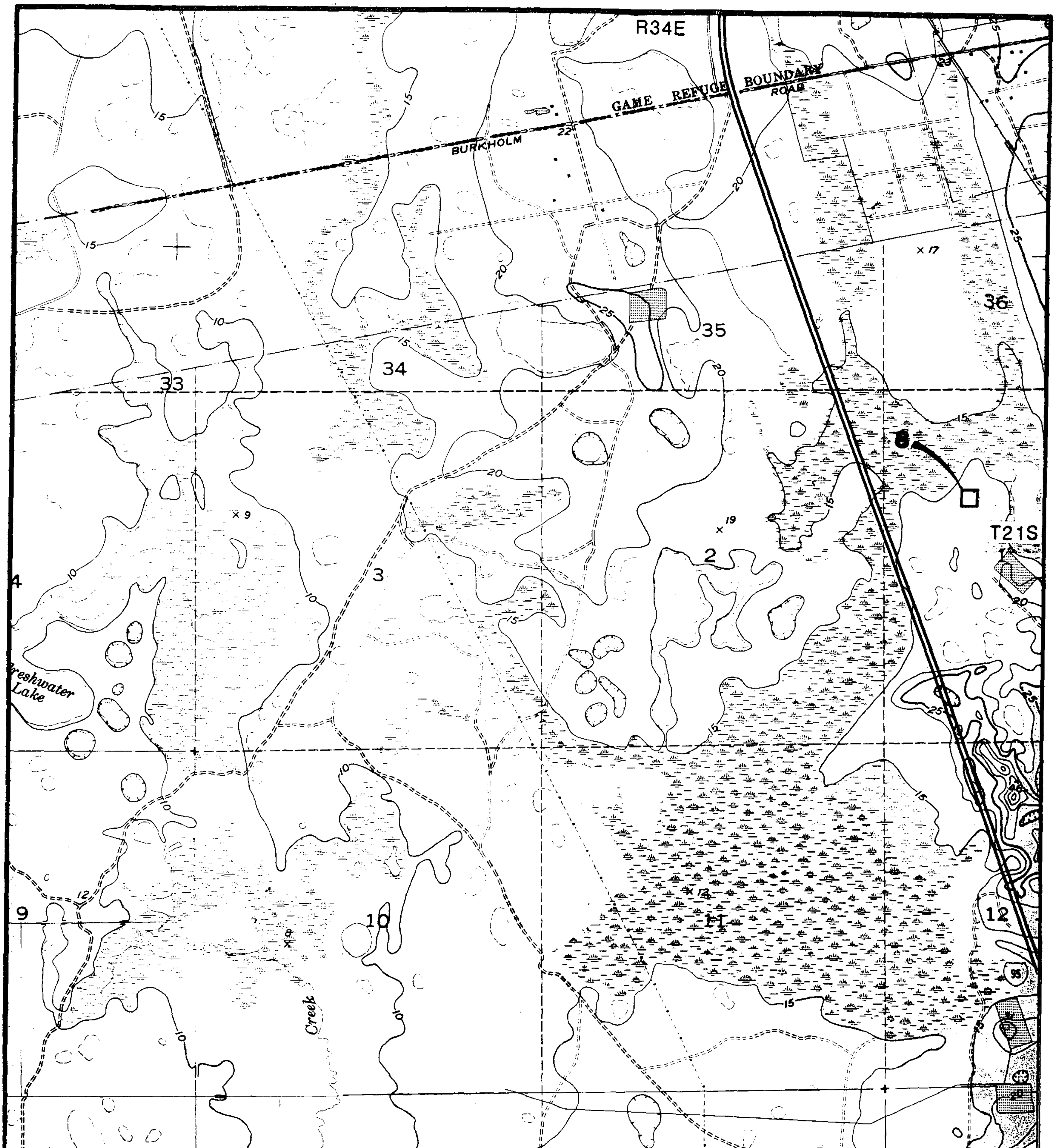
The range of resistivity of the upper layer may vary between 33 ohm-m and 38 ohm-m. Clay layers in the Hawthorn Group and younger sediments may be the cause of this value of resistivity, and hence no information about chloride concentration is derived for the upper 183 ft.

Summary of Results of TDEM Measurements at North Brevard Waste Water Treatment Plant (Site 8)

From the TDEM measurements the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted to occur at an elevation of 168 ft below msl, and below that depth chloride concentrations in excess of 10,000 mg/l chloride are expected.

2) Because no distinction could be made between the resistivity value of the Hawthorn Group, surficial sediments, and the carbonate rocks of the Upper Floridan, no information about chloride concentration could be inferred above the highly saline water interface.



1 TDEM Sounding

0 2000 4000 Feet

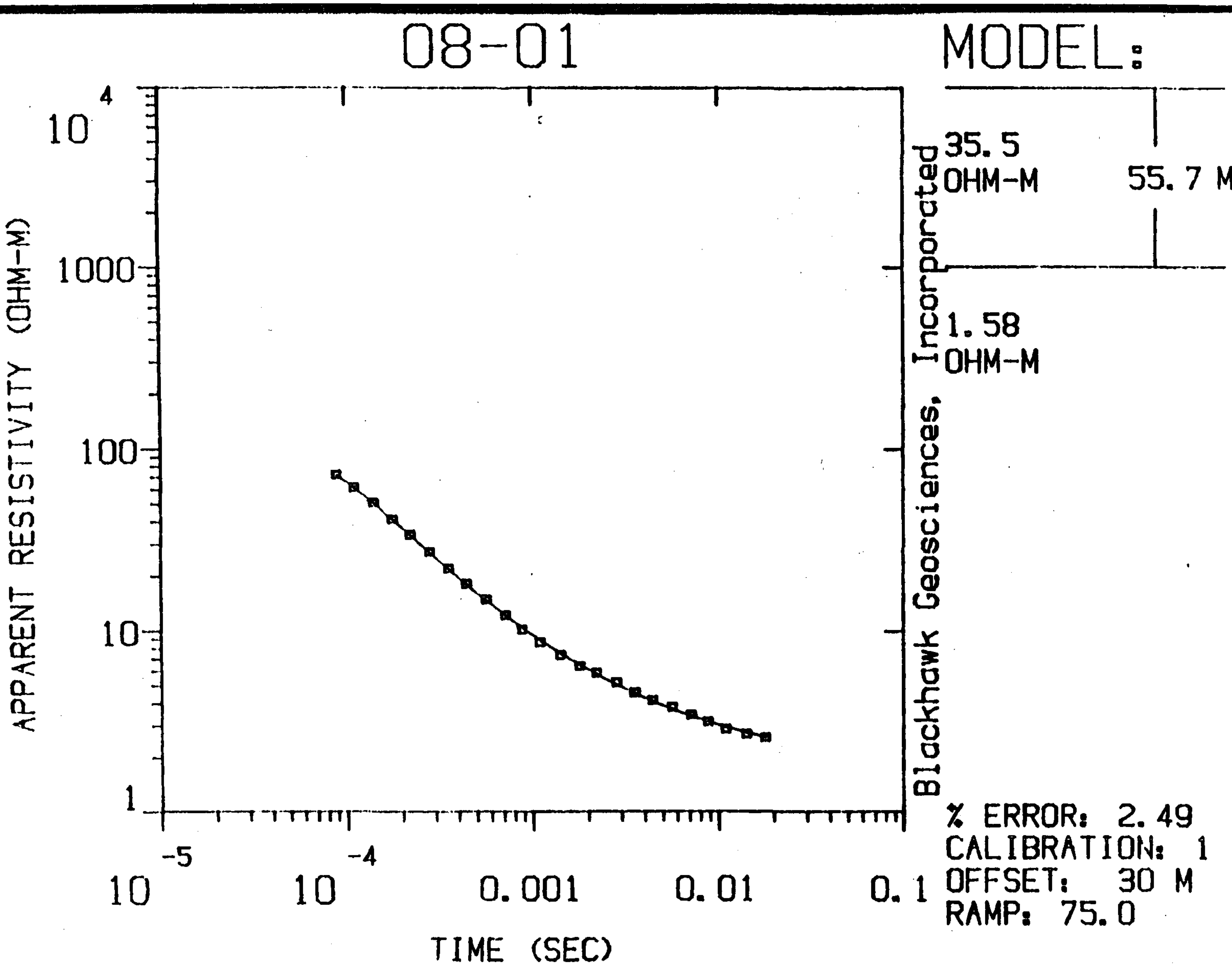
N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 8
NORTH BREVARD WWTP

ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 Figure 4-9.1



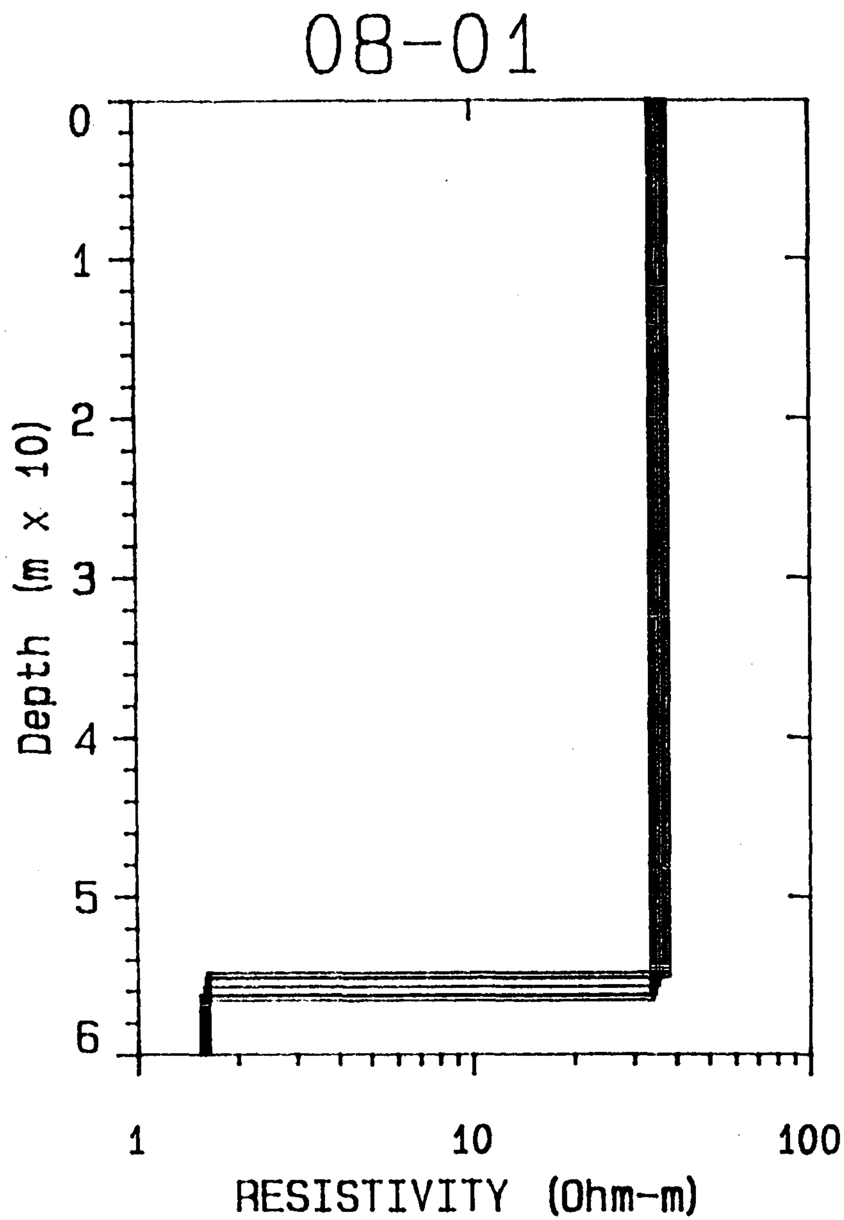
BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

NORTH BREVARD WASTE WATER TREATMENT PLANT SITE 8

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-9.2**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION
NORTH BREVARD WASTE WATER
TREATMENT PLANT SITE 8
St. Johns River Water Management District

PROJECT NO: 91034 Figure 4-9.3

MODEL: 2 LAYERS

RESISTIVITY	THICKNESS	ELEVATION		CONDUCTANCE (S)	
(OHM-M)	(M)	(M)	(FEET)	LAYER	TOTAL
		4.6	15.0		
35.50	55.7	-51.2	-167.9	1.6	1.6
1.58					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	7.19E+01	7.16E+01	0.332	
2	1.10E-04	6.13E+01	6.17E+01	-0.655	
3	1.40E-04	5.06E+01	5.07E+01	-0.242	
4	1.77E-04	4.11E+01	4.12E+01	-0.042	
5	2.20E-04	3.40E+01	3.37E+01	0.748	
6	2.80E-04	2.72E+01	2.70E+01	0.731	
7	3.55E-04	2.20E+01	2.18E+01	0.827	
8	4.43E-04	1.81E+01	1.80E+01	0.851	
9	5.64E-04	1.49E+01	1.47E+01	1.054	
10	7.13E-04	1.21E+01	1.22E+01	-0.440	
11	8.81E-04	1.02E+01	1.04E+01	-2.464	
12	1.10E-03	8.63E+00	8.91E+00	-3.125	
13	1.41E-03	7.34E+00	7.54E+00	-2.533	
14	1.80E-03	6.38E+00	6.50E+00	-1.731	
15	2.21E-03	5.88E+00	5.76E+00	1.960	
16	2.83E-03	5.21E+00	5.06E+00	2.784	
17	3.55E-03	4.58E+00	4.53E+00	1.065	
18	4.43E-03	4.17E+00	4.11E+00	1.657	
19	5.64E-03	3.82E+00	3.72E+00	2.627	
20	7.13E-03	3.46E+00	3.41E+00	1.558	
21	8.81E-03	3.18E+00	3.18E+00	0.099	
22	1.10E-02	2.89E+00	2.97E+00	-2.561	
23	1.41E-02	2.72E+00	2.77E+00	-1.627	
24	1.80E-02	2.59E+00	2.61E+00	-0.544	

R: 30. X: 0. Y: 30. DL: 60. REQ: 33. CF: 1.0000
CLHZ ARRAY, 24 DATA POINTS, RAMP: 75.0 MICROSEC, DATA: 08-01
NORTH BREVARD WWTP

RMS LOG ERROR: 1.07E-02, ANTILOG YIELDS 2.4853 %

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE
NORTH BREVARD WASTE WATER
TREATMENT PLANT SITE 8
St. Johns River Management District

PROJECT NO: 91034 **Table 4-9.1**

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

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	

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	33.439	35.499	37.946
	2	1.531	1.580	1.633
THICK	1	54.849	55.749	56.632
DEPTH	1	54.849	55.749	56.632

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

NORTH BREVARD WASTE WATER
TREATMENT PLANT SITE 8
St. Johns River Management District

PROJECT NO: 91034 **Table 4-9.1**

4.10 PARRISH GROVE (SITE 9)

Location and Geoelectric Section

The detailed location map of this sounding is shown in Figure 4-10.1. Two soundings were made at this site. The data in the first sounding was distorted due to a buried pipeline near one side of the transmitter loop. A second sounding was repositioned 200 ft away from the pipeline and undistorted data were obtained at that location. This is the location shown in Figure 4-10.1. The TDEM data and the inverted geoelectric section is shown in Figure 4-10.2 and consists of a two layer section.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective depth of the measurement is 2.4 ohm-m, and it is first encountered at a depth of 212 ft below surface or at an elevation of 182 ft below msl. Assuming an average porosity of 25% the chloride concentration below that depth is expected to exceed 10,000 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

The resistivity of the upper 212 ft likely include portions of the carbonate rocks below the Hawthorn Group and younger sediments. Since the resistivity of 31 ohm-m may have been influenced by clay layers, no conclusions about chloride concentrations can be drawn for the upper 212 ft.

Accuracy of Measurement and Interpretation

Figure 4-10.3 shows the evaluation of equivalence of the TDEM sounding at this site, and the inversion table (Table 4-10.1) lists the upper and lower bounds of the parameters of the geoelectric section. The range of equivalence of all parameters is relatively small. The error of measurement in determining the elevation of the interface with saline water is expected to be ± 5% of total depth, or about ± 10 ft.

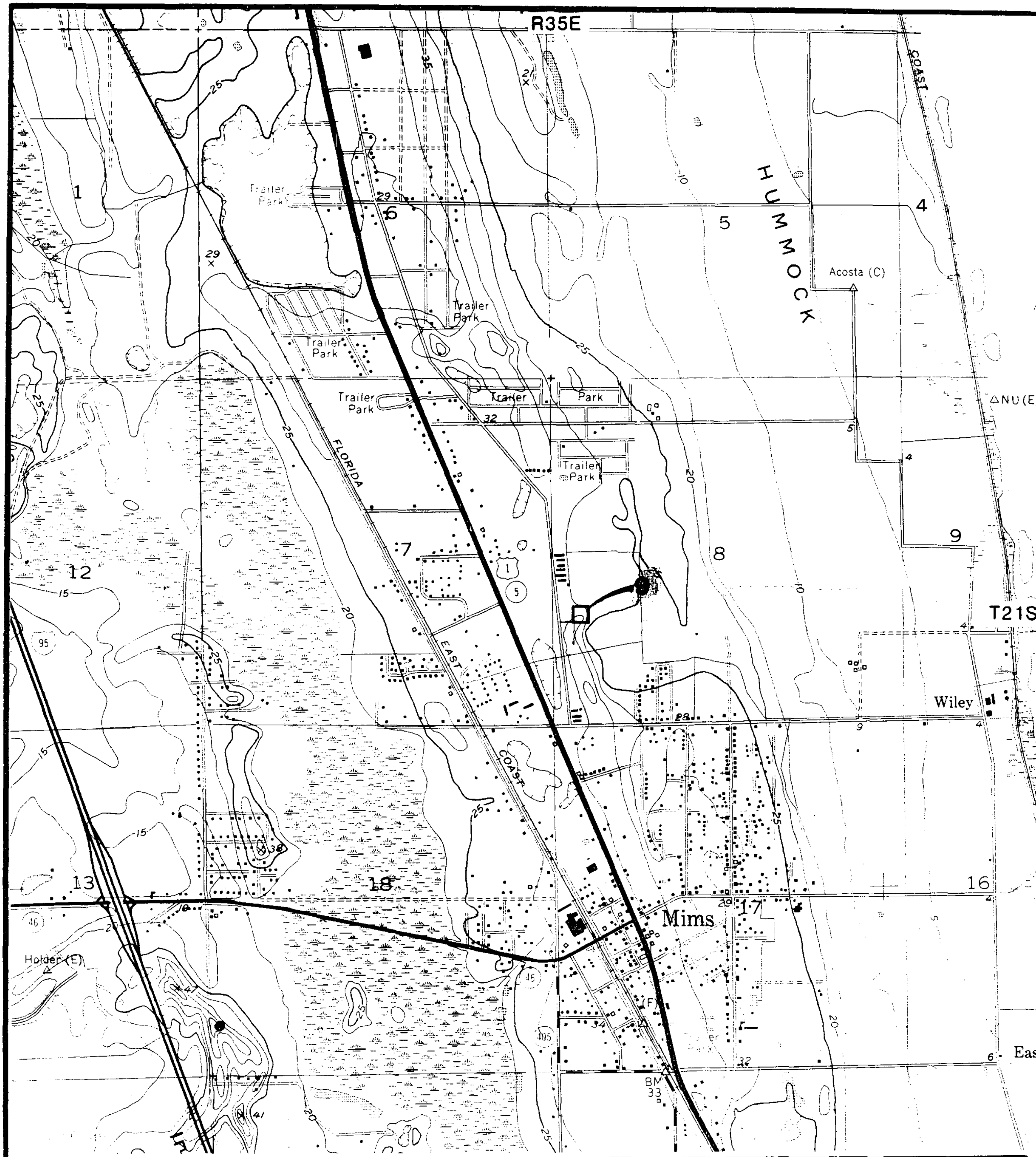
The range of resistivity of the upper layer may vary between 29 ohm-m and 33 ohm-m. Since clay layers in the Hawthorn Group and younger sediments may be the cause of this resistivity value, no information about chloride concentrations were inferred for the upper 212 ft.

Summary of Results of TDEM Measurements at Parrish Grove (Site 9)

From the TDEM measurements the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted to occur at an elevation of 182 ft below msl, and below that depth chloride concentrations in excess of 10,000 mg/l chloride are expected.

2) Because no distinction could be made between the resistivity value of the Hawthorn Group, the surficial sediments, and the carbonate rocks of the Upper Floridan, no information about chloride concentration could be inferred above the highly saline water interface.



1 TDEM Sounding

0 2000 4000 Feet

N

BLACKHAWK GEOSCIENCES, INC.

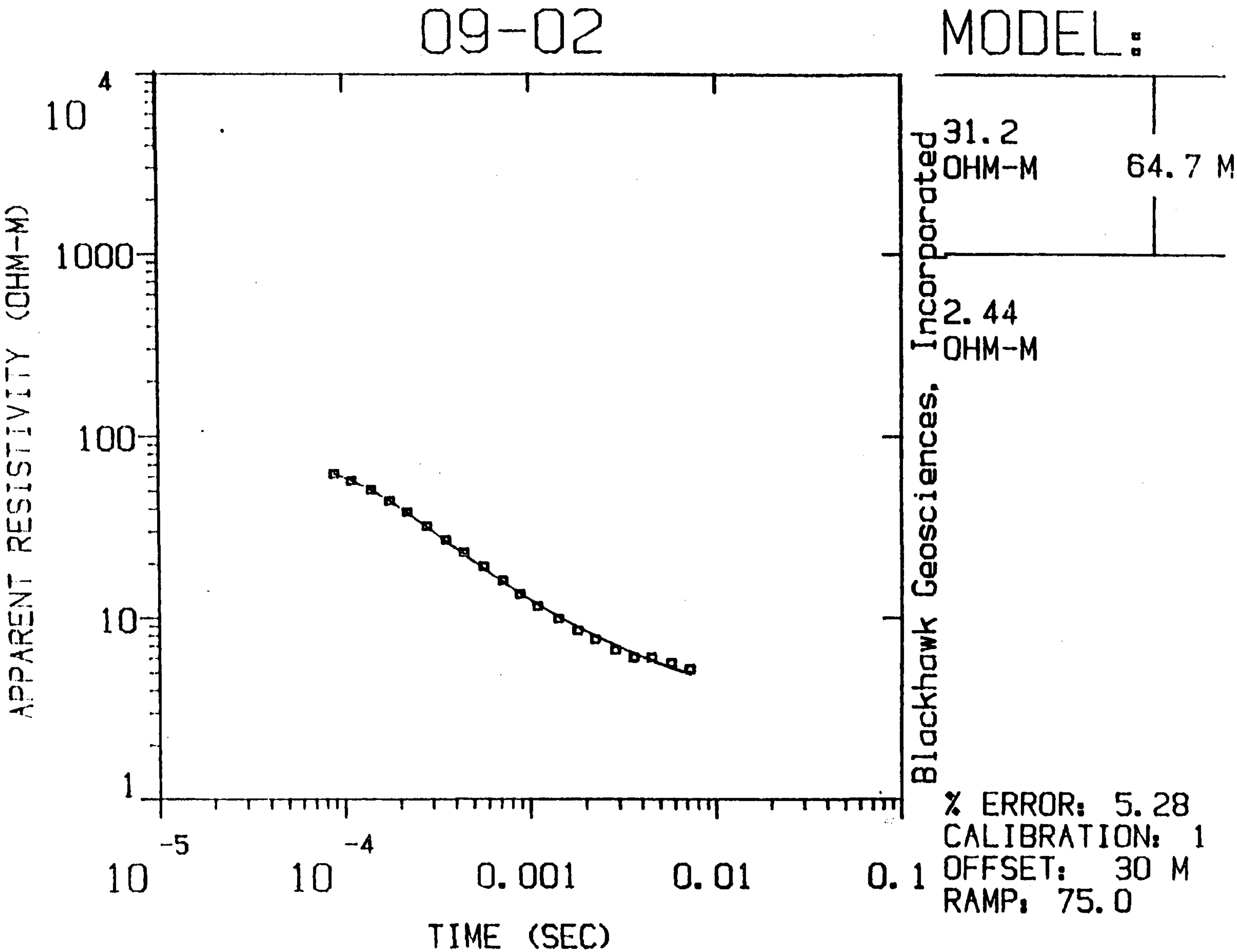
LOCATION MAP SITE 9

PARRISH GROVE

ST. JOHNS RIVER

WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 Figure 4-10.1

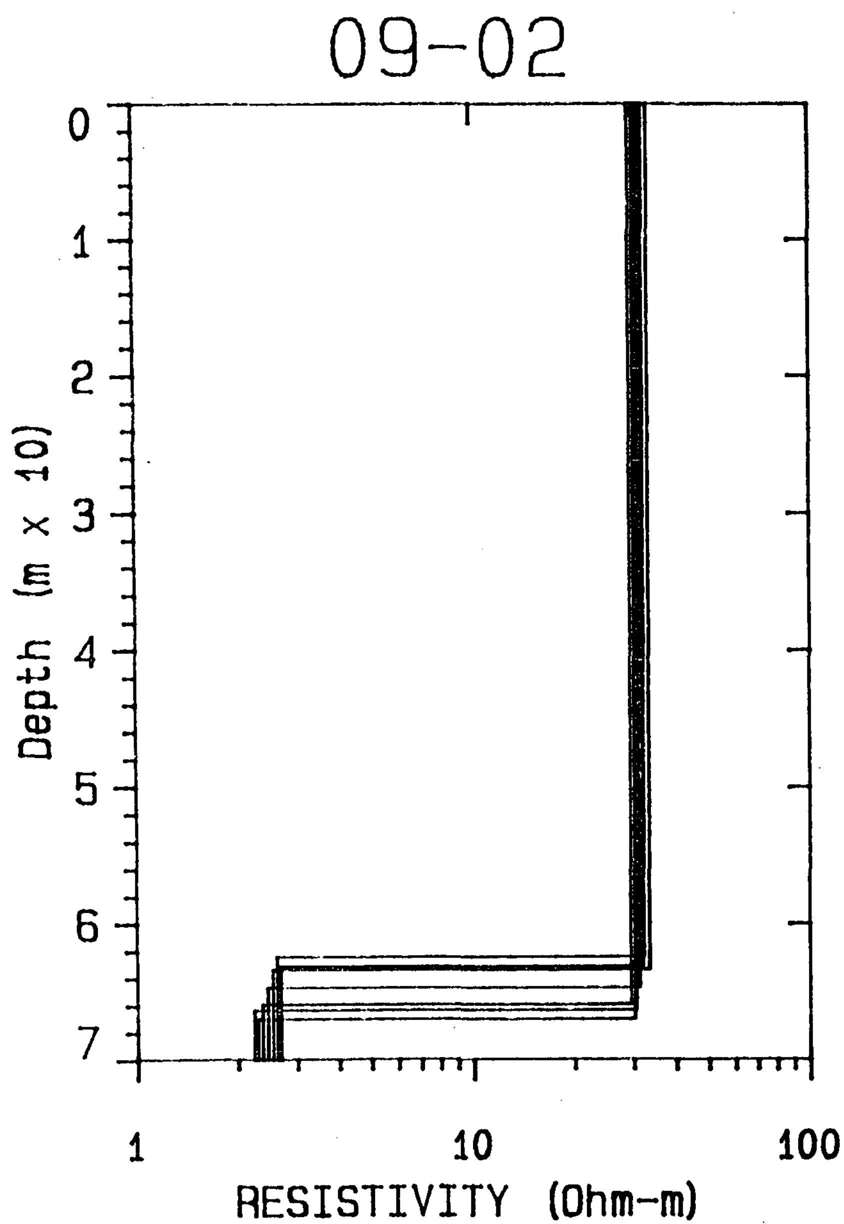


BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

PARRISH GROVE
SITE 9
St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-10.2**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

PARRISH GROVE
SITE 9

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-10.3**

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		9.1	30.0		
31.19	64.7	-55.6	-182.4	2.1	2.1
2.44					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	6.21E+01	6.24E+01	-0.450	
2	1.10E-04	5.70E+01	5.73E+01	-0.527	
3	1.40E-04	5.08E+01	5.09E+01	-0.211	
4	1.77E-04	4.42E+01	4.43E+01	-0.165	
5	2.20E-04	3.84E+01	3.81E+01	0.675	
6	2.80E-04	3.22E+01	3.18E+01	0.984	
7	3.55E-04	2.70E+01	2.65E+01	1.804	
8	4.43E-04	2.30E+01	2.23E+01	2.728	
9	5.64E-04	1.92E+01	1.86E+01	3.076	
10	7.13E-04	1.60E+01	1.57E+01	1.944	
11	8.81E-04	1.35E+01	1.36E+01	-0.797	
12	1.10E-03	1.16E+01	1.18E+01	-2.079	
13	1.41E-03	9.84E+00	1.01E+01	-2.838	
14	1.80E-03	8.47E+00	8.84E+00	-4.201	
15	2.22E-03	7.55E+00	7.91E+00	-4.524	
16	2.85E-03	6.58E+00	7.01E+00	-6.107	
17	3.60E-03	6.01E+00	6.32E+00	-4.899	
18	4.49E-03	6.02E+00	5.78E+00	4.047	
19	5.70E-03	5.63E+00	5.29E+00	6.296	
20	7.19E-03	5.21E+00	4.90E+00	6.427	

R: 30. X: 0. Y: 30. DL: 60. REQ: 33. CF: 1.0000
CLHZ ARRAY, 20 DATA POINTS, RAMP: 75.0 MICROSEC, DATA: 09-02
PARRISH GROVE

RMS LOG ERROR: 2.23E-02, ANTILOG YIELDS 5.2792 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE
PARRISH GROVE
SITE 9
St. Johns River Management District

PROJECT NO: 91034 **Table 4-10.1**

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

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	29.407	31.190	33.340
	2	2.231	2.444	2.674
THICK	1	62.447	64.725	67.029
DEPTH	1	62.447	64.725	67.029

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

PARRISH GROVE

SITE 9

St. Johns River Management District

PROJECT NO: 91034

Table 4-10.1

4.11 NEW SMYRNA BEACH WESTERN WELL FIELD (SITE 10)

Location and Geoelectric Section

The detailed location of this sounding is shown in Figure 4-11.1. The interpreted geoelectric section is shown in Figure 4-11.2 and consists of three layers.

Geologic Interpretation of Geoelectric Section

The upper layer in the geoelectric section is 263 ft thick and has a resistivity of 35 ohm-m. Since the regional information by Tibbals (1990) indicate the Hawthorn Group and younger sediments to be 100 ft thick, the first layer in the geoelectric section, therefore, also likely will include portions of the upper carbonate rocks of the Floridan aquifer. The resistivity value of this layer is as much determined by lithology as by water quality, and no inferences about water quality are drawn for this depth interval.

Geophysical logs were available for a well drilled in the same section. In Figure 4-11.3 the geoelectric section derived from TDEM soundings and the resistivity log run in the well are compared. Over the depth interval between the top of the casing (about 100 ft) and about 280 ft below surface, the average value of resistivity displayed by the log is about 50 ohm-m, and at about 280 ft below surface this increases to about 100 ohm-m. There is thus correspondence between resistivity logs and TDEM derived geoelectric sections manifested by:

i) reasonable agreement in depth of occurrence of change in resistivity (263 ft versus 280 ft); and

ii) both resistivity log and TDEM derived geoelectric section show an increase in resistivity at that depth.

There is some difference in absolute values of resistivity measured.

Depth of First Occurrence of Saline Water

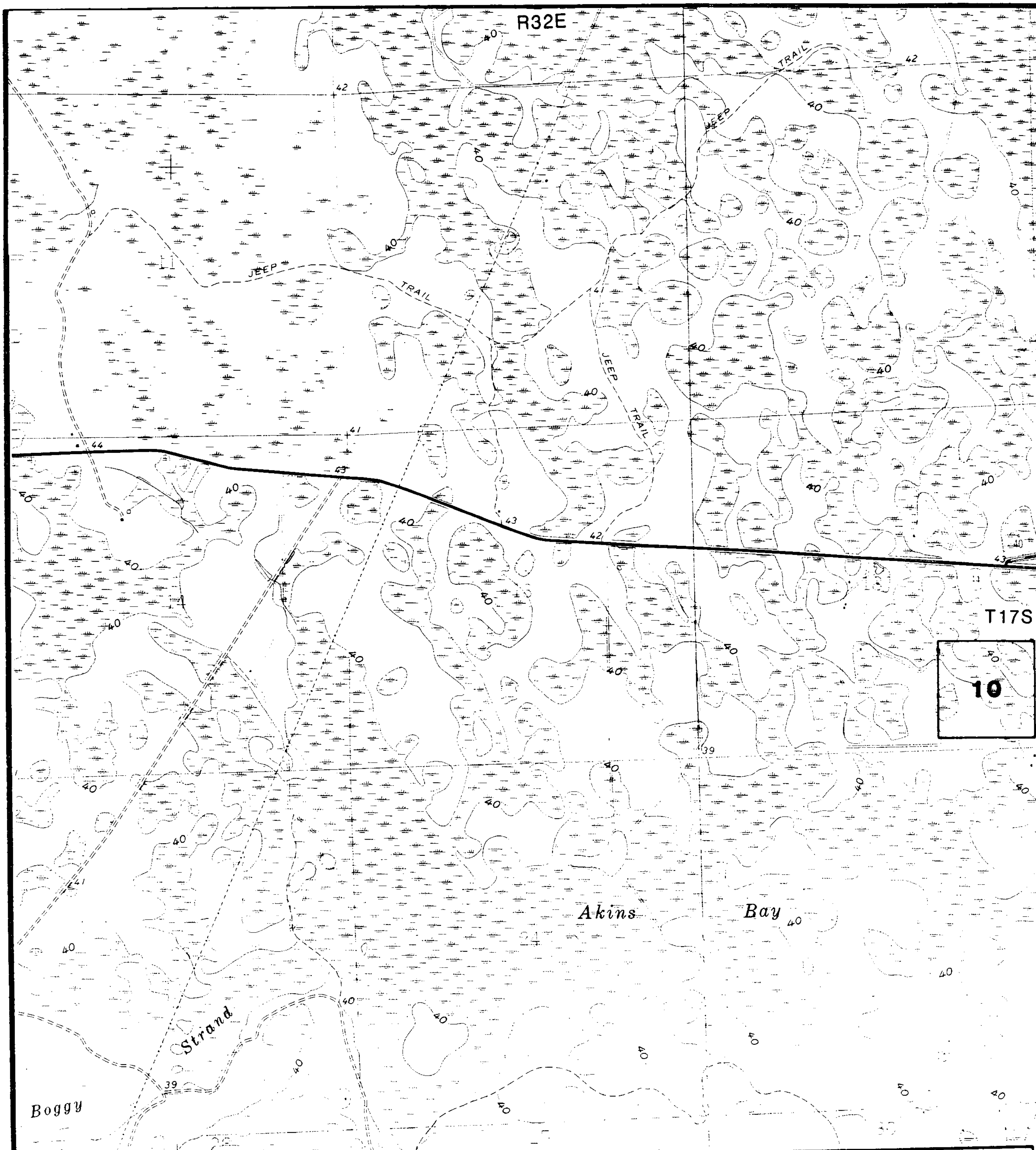
The lowest resistivity encountered in the geoelectric section is 9 ohm-m and it occurs at a depth of 949 ft below surface or at an elevation of 909 ft below msl. Assuming a porosity of 25% this would correspond to a chloride concentration in excess of 3,420 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

The resistivity of the second layer in the geoelectric section in the elevation interval between 223 ft below msl and 909 ft below msl is 154 ohm-m. Assuming a porosity of 25% the ground water in the carbonate rocks over this interval is expected to have a chloride concentration less than 250 mg/l. The depth to the 250 mg/l isochlor is expected to coincide with the resistivity boundary between 154 ohm-m and 9 ohm-m at an elevation of 909 ft below msl. Likely a transition zone from ground water with chloride concentrations less than 250 mg/l to in excess of 3,000 mg/l will occur. This transition zone is not determined by the geoelectric section derived from TDEM.

Accuracy of Measurement and Interpretation

Figure 4-11.4 shows the evaluation of equivalence for the TDEM sounding at this site, and the inversion table (Table 4-11.1) lists the upper and lower bounds of the parameters of the geoelectric section. The range in the depth to the saline layer with a chloride concentration in excess of 3,420 mg/l is about 10% of total depth, or about ± 90 ft. The range of equivalence in the resistivity of the second layer, the main section of the Floridan aquifer, is



1 TDEM Sounding

0 2000 4000 Feet

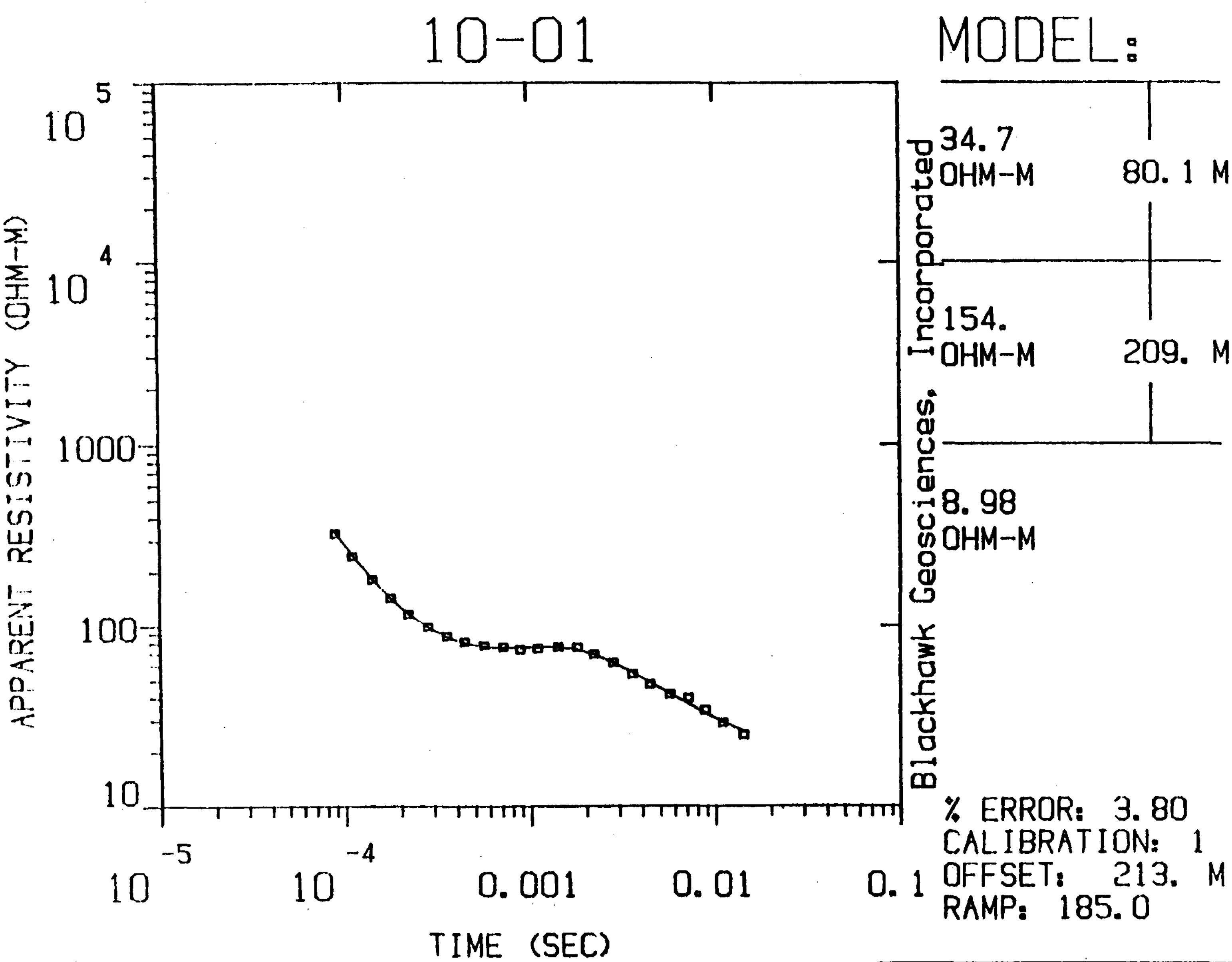
N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 10
NEW SMYRNA BEACH
WESTERN WELL FIELD
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034

Figure 4-11.1

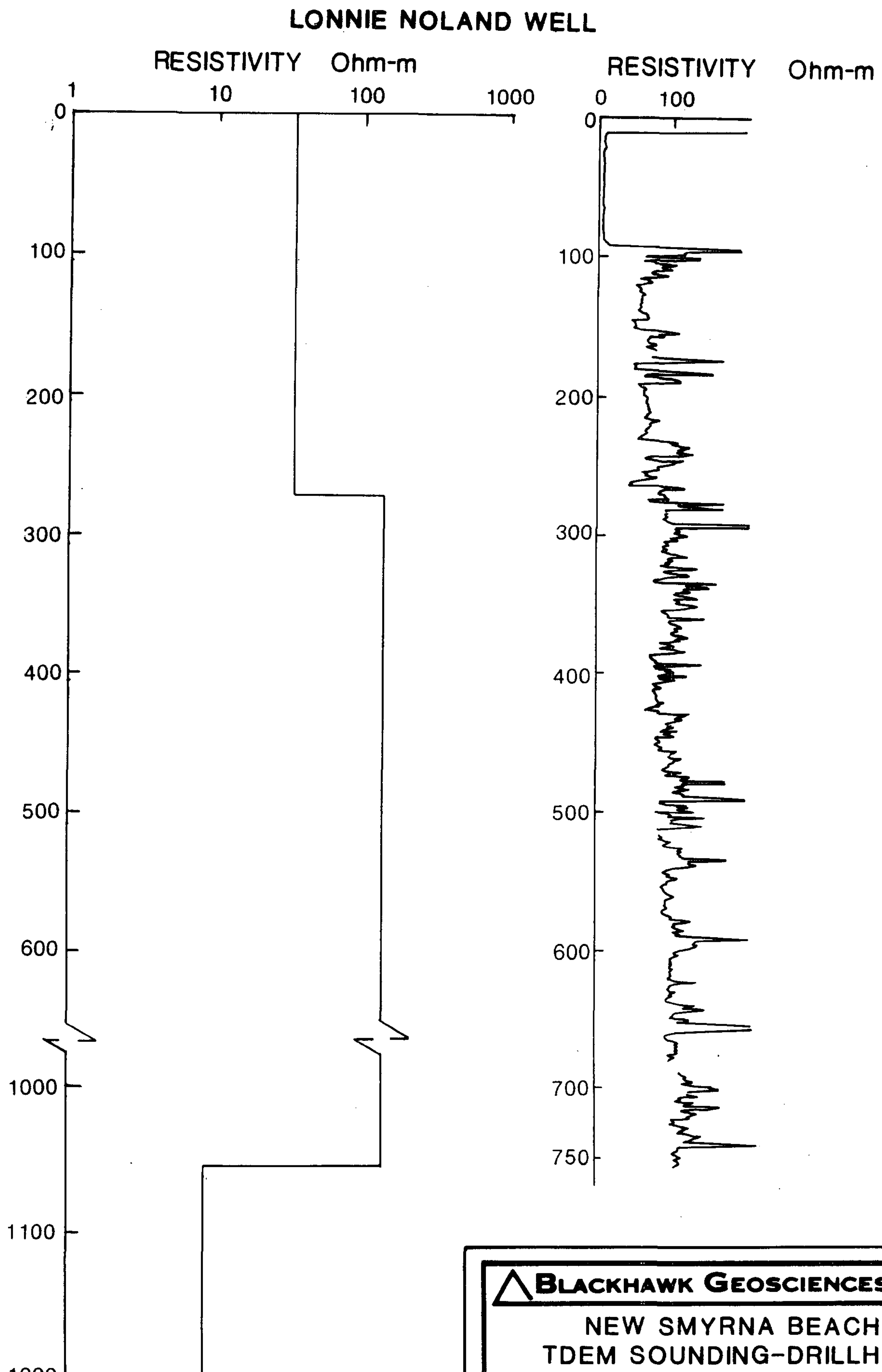


BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

NEW SMYRNA BEACH WESTERN WELL FIELD
SITE 10
St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-11.2**

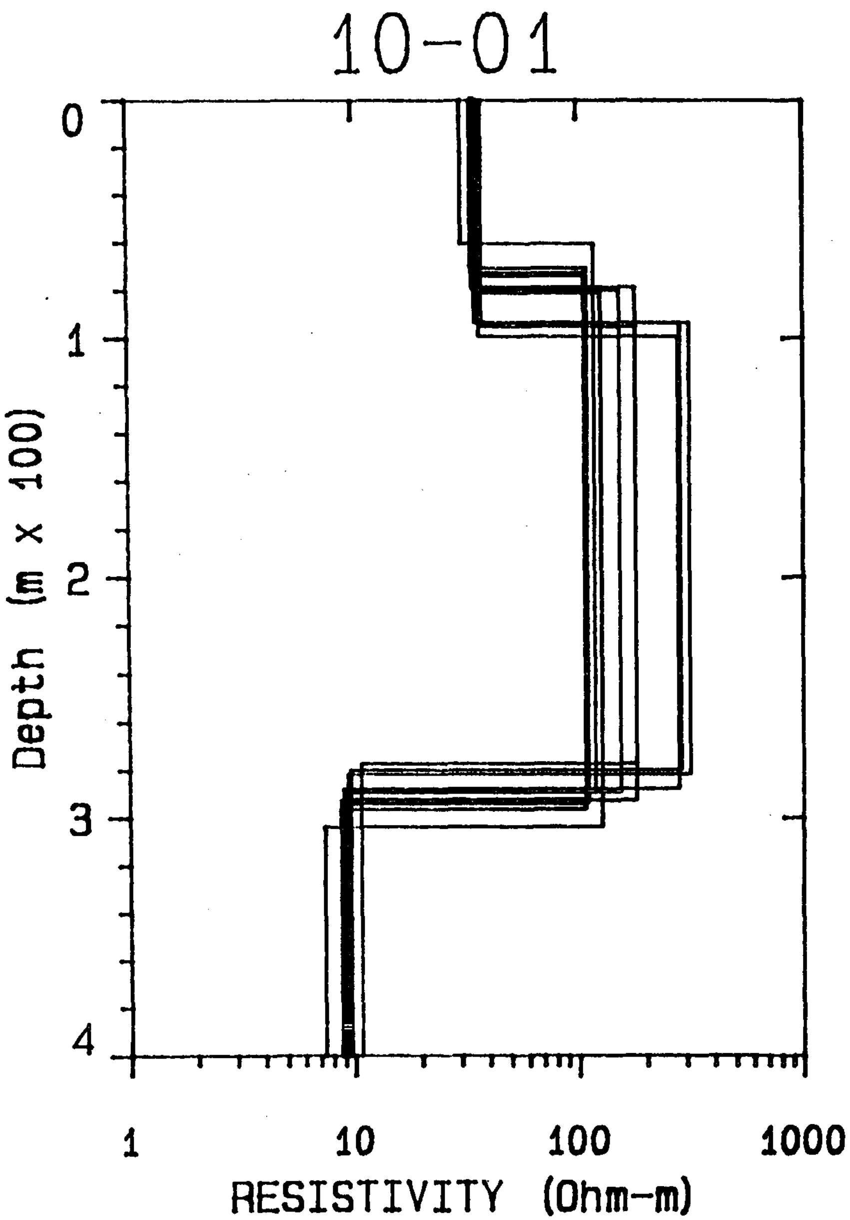


BLACKHAWK GEOSCIENCES, INC.

NEW SMYRNA BEACH
TDEM SOUNDING-DRILLHOLE
COMPARISON

St. Johns River Management District

PROJECT NO: 91034 Figure 4-11.3



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION
NEW SMYRNA BEACH WESTERN WELL FIELD
SITE 10
St. Johns River Water Management District

PROJECT NO: 91034 Figure 4-11.4

MODEL: 3 LAYERS

RESISTIVITY	THICKNESS	ELEVATION		CONDUCTANCE (S)	
(OHM-M)	(M)	(M)	(FEET)	LAYER	TOTAL
		12.2	40.0		
34.69	80.1	-67.9	-222.7	2.3	2.3
153.69	209.1	-277.0	-908.8	1.4	3.7
8.98					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	3.31E+02	3.36E+02	-1.536	
2	1.10E-04	2.46E+02	2.51E+02	-1.794	
3	1.40E-04	1.83E+02	1.85E+02	-1.244	
4	1.77E-04	1.44E+02	1.43E+02	0.330	
5	2.20E-04	1.16E+02	1.17E+02	-1.026	
6	2.80E-04	9.82E+01	9.83E+01	-0.045	
7	3.55E-04	8.73E+01	8.66E+01	0.855	
8	4.43E-04	8.10E+01	8.00E+01	1.258	
9	5.64E-04	7.74E+01	7.62E+01	1.594	
10	7.13E-04	7.60E+01	7.51E+01	1.125	
11	8.81E-04	7.37E+01	7.55E+01	-2.380	
12	1.10E-03	7.46E+01	7.63E+01	-2.106	
13	1.41E-03	7.61E+01	7.61E+01	-0.092	
14	1.80E-03	7.58E+01	7.36E+01	3.066	
15	2.21E-03	6.92E+01	6.91E+01	0.045	
16	2.80E-03	6.20E+01	6.24E+01	-0.547	
17	3.55E-03	5.38E+01	5.50E+01	-2.147	
18	4.43E-03	4.74E+01	4.84E+01	-1.946	
19	5.64E-03	4.16E+01	4.20E+01	-0.883	
20	7.13E-03	3.97E+01	3.68E+01	7.791	
21	8.81E-03	3.42E+01	3.28E+01	4.265	
22	1.10E-02	2.89E+01	2.93E+01	-1.488	
23	1.41E-02	2.48E+01	2.60E+01	-4.657	

R: 213. X: 0. Y: 213. DL: 426. REQ: 237. CF: 1.0000
TDHZ ARRAY, 23 DATA POINTS, RAMP: 185.0 MICROSEC, DATA: 10-01
NEW SMYRNA BEACH WESTERN WELL FIELD

RMS LOG ERROR: 1.62E-02, ANTILOG YIELDS 3.8013 %

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

NEW SMYRNA BEACH WESTERN WELL FIELD
SITE 10
St. Johns River Management District

PROJECT NO: 91034 Table 4-11.1

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:

"F" MEANS FIXED PARAMETER

	P 1	P 2	P 3	T 1	T 2
P 1	0.99				
P 2	-0.02	0.15			
P 3	0.00	-0.04	0.96		
T 1	-0.02	-0.19	0.00	0.93	
T 2	0.01	0.13	0.01	0.03	0.98

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	30.544	34.689	37.583
	2	107.440	153.693	313.308
	3	7.316	8.981	10.696
THICK	1	60.760	80.084	99.551
	2	186.176	209.110	228.708
DEPTH	1	60.760	80.084	99.551
	2	277.223	289.194	304.026

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

NEW SMYRNA BEACH WESTERN WELL FIELD

SITE 10

St. Johns River Management District

PROJECT NO: 91034 Table 4-11.1

between 107 ohm-m and 313 ohm-m. For this range of resistivity chloride concentration less than 250 mg/l are expected.

Summary of Results of TDEM Measurements at the New Smyrna Beach Western Well Field (Site 10)

From the TDEM measurements at New Smyrna Beach Western Well Field, the following information about aquifer characteristics and water quality was derived:

1) The depth of occurrence of saline water was interpreted at a depth of 909 ft below msl. The chloride concentration at that depth is expected to exceed 3,420 mg/l.

2) On the basis of the resistivity value of about 154 ohm-m measured for the carbonate rock of the Upper Floridan aquifer over the elevation interval between 223 ft to 909 ft below msl, the chloride concentration is expected to be less than 250 mg/l. The depth of occurrence of the 250 mg/l isochlor is expected to approximately coincide with the resistivity boundary measured at an elevation of about 909 ft below msl.

4.12 *ORANGE COUNTY LANDFILL (SITE 11)*

The detailed location map of the sounding is shown in Figure 4-12.1. The measured TDEM data and the inverted geoelectric section is shown in Figure 4-12.2 and it consists of a three layer section.

Geologic Interpretation of Geologic Section

A well located approximately 3 miles northeast of the site was completed to a depth of 1,400 ft. The lithologic log of that well (Fig. 4-12.3) shows surficial sands and the Hawthorn Group to extend to approximately 250 ft below surface. The upper layer in the geoelectric section is 288 ft and has a resistivity of 33 ohm-m. If the information in the drilled well 3 miles away can be extrapolated to the location of the TDEM measurement, the upper layer can be expected to represent the surficial sands and the Hawthorn Group. The resistivities of the two layers below 288 ft represent different strata within the carbonate rocks of the Floridan aquifer.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective depth of measurement is 10.6 ohm-m, and it is first encountered at an elevation of about 2,304 ft below msl. The resistivity below that depth is 10.6 ohm-m, and at an average porosity of 25%, that value corresponds to a chloride content in excess of 2,880 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

The resistivity of the interval between elevations of 203 ft below msl and 2,304 ft below msl is 708 ohm-m. At an average porosity of 25%, the chloride content of this interval is expected to be less than 100 mg/l. The 250 mg/l isochlor is expected to approximately correspond with the elevation of the boundary between 708 ohm-m and 10.6 ohm-m at 2,304 ft below msl. A transition zone from ground water with a low chloride content to a chloride content in excess of 2,880 mg/l can be expected. Such transition zones are difficult to map with surface geophysics.

Accuracy of Measurement and Interpretation

Figure 4-12.4 shows the evaluation of equivalence of the TDEM sounding at this site and the inversion table (Table 4-12.1) lists the upper and lower bounds of the parameters of the geoelectric section. The depth to the saline water is determined with an accuracy of about ± 5% of total depth.

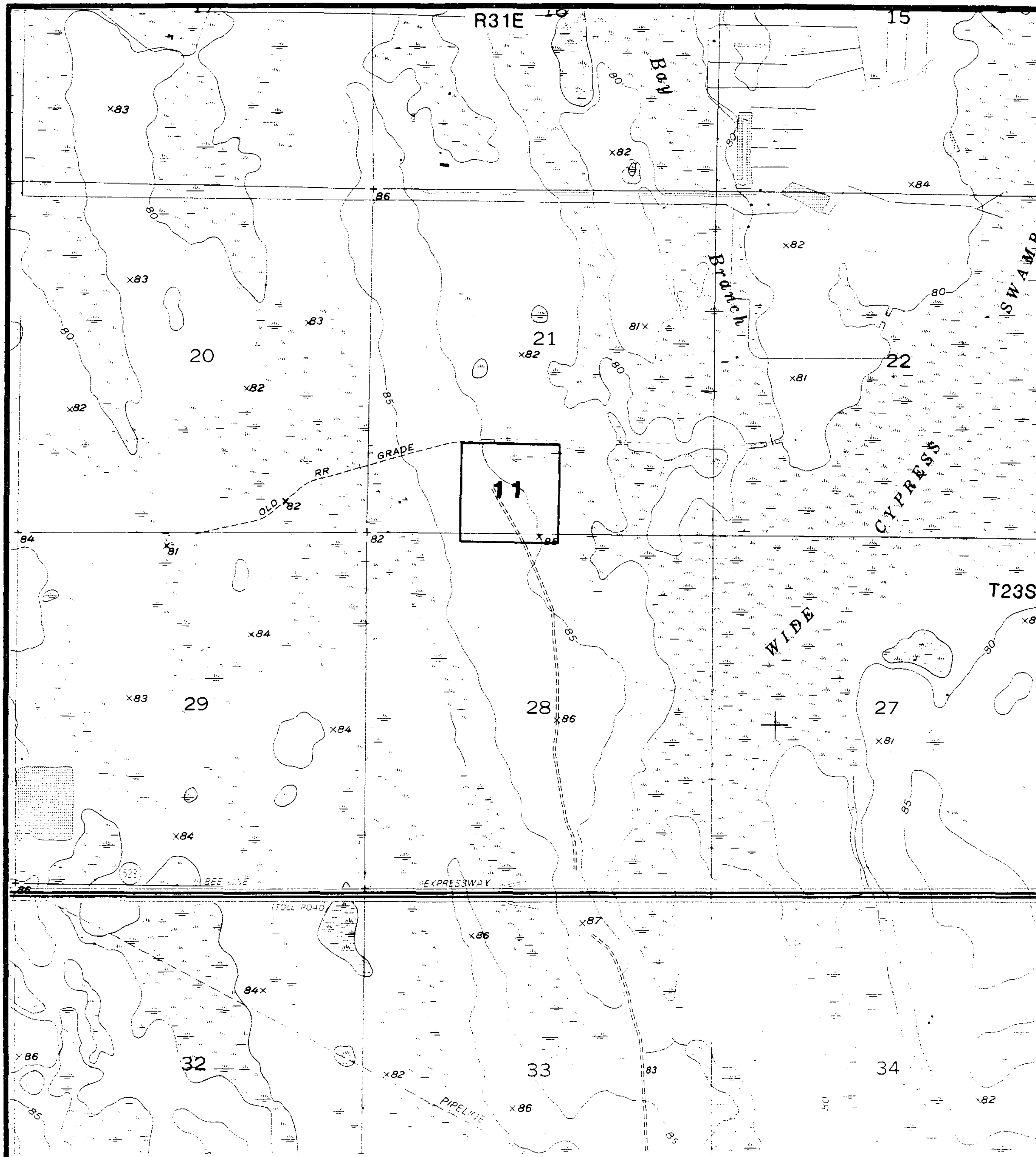
The equivalence in the resistivity of the layer at elevations between 203 ft below msl and 2,304 ft below msl is between 441 ohm-m and 1,303 ohm-m. Although this range of equivalence is large, it does not negate the conclusion that the chloride content over this depth interval is well below 250 mg/l.

Summary of Results of TDEM Measurements at the Orange County Landfill (Site 11)

From the TDEM soundings the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted to occur at an elevation of 2,304 ft below msl, and below that elevation chloride concentrations in excess of 2,880 mg/l chloride are expected.

2) Below the Hawthorn Group, at an elevation of 203 ft below msl and above the interface with saline water at 2,304 ft below msl, the chloride content of ground water is expected to be less than 250 mg/l.



1 TDEM Sounding

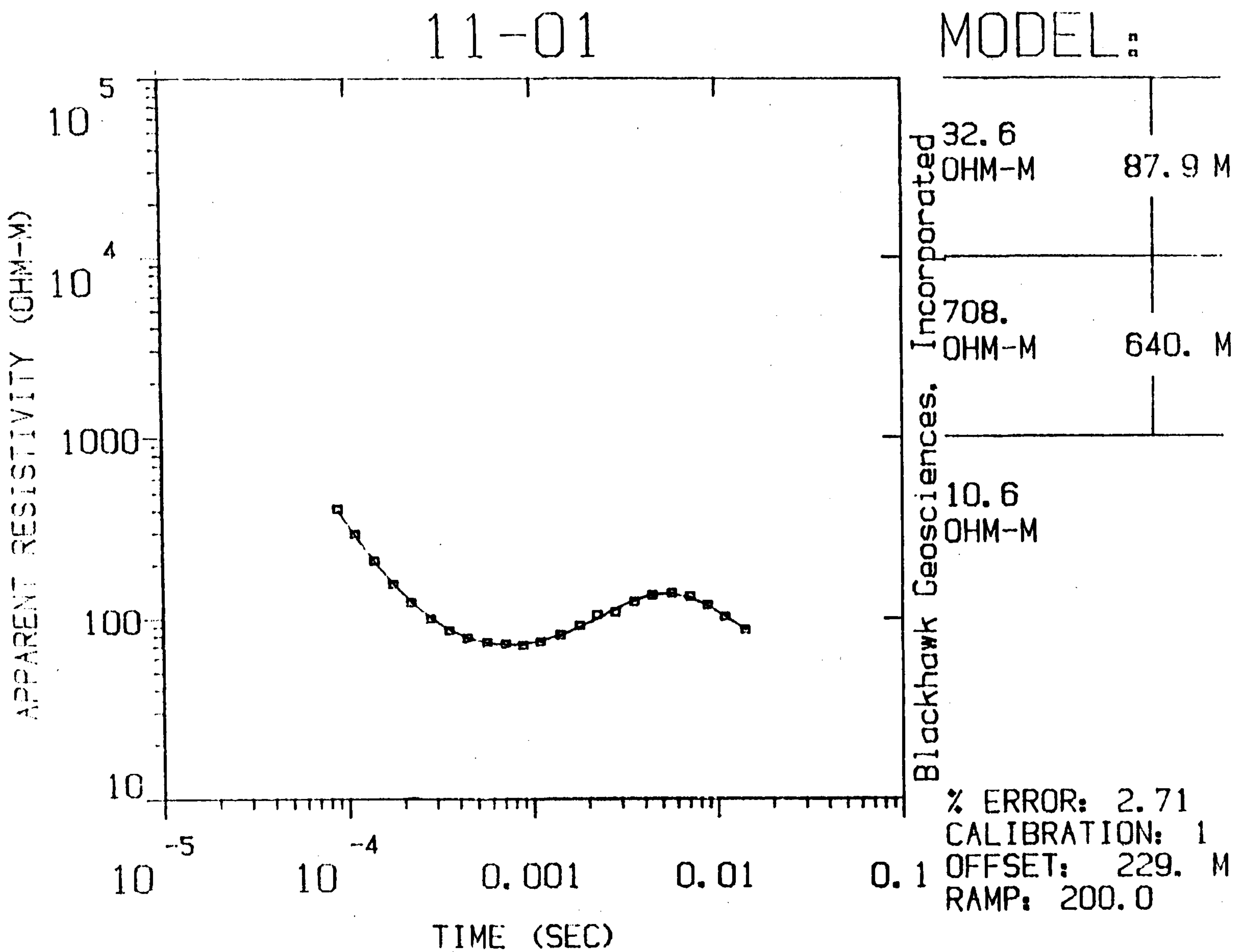
0 2000 4000 Feet

N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE11
ORANGE COUNTY LANDFILL
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 **Figure 4-12.1**

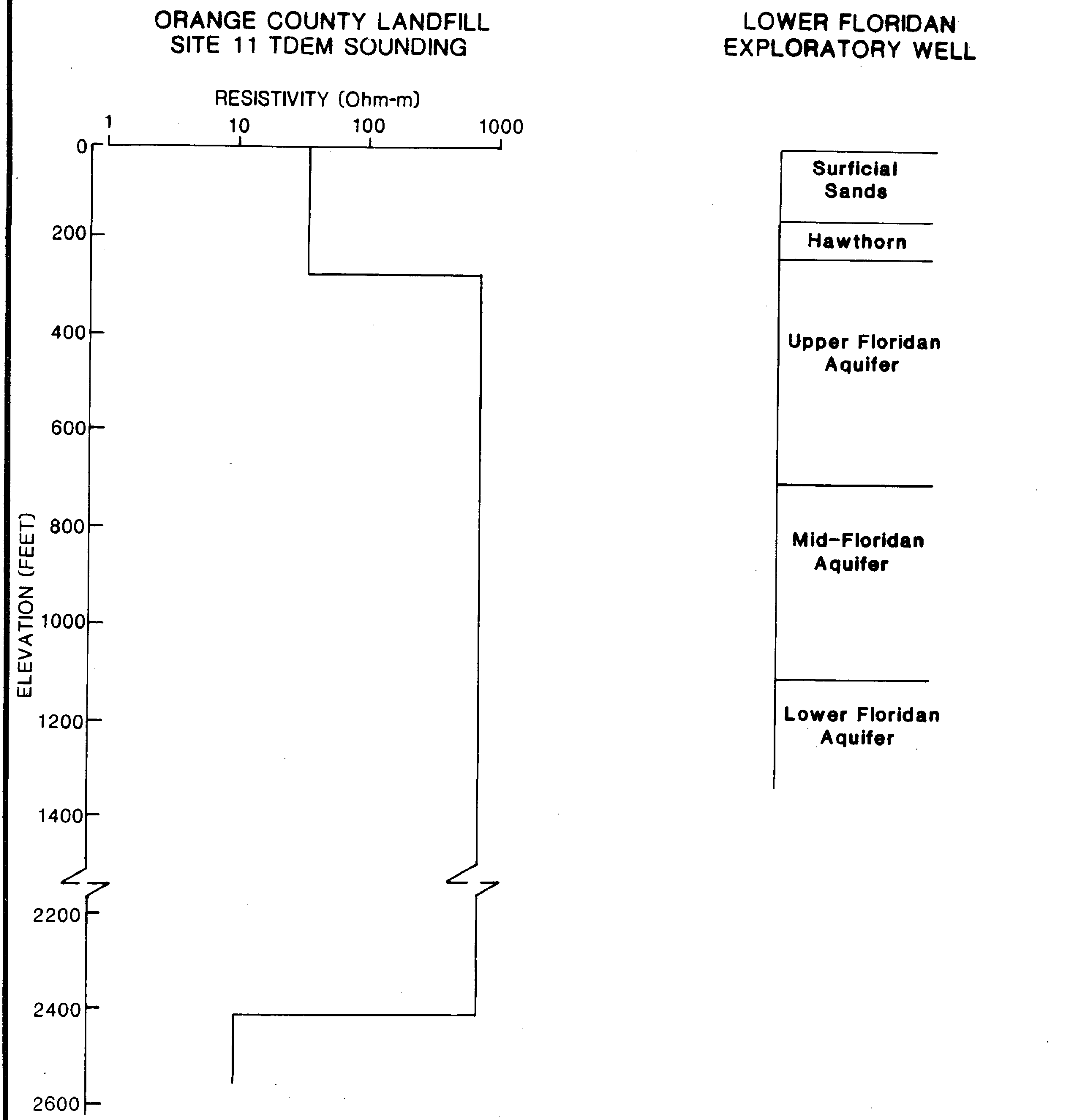


BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

ORANGE COUNTY LANDFILL
SITE 11
St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-12.2**

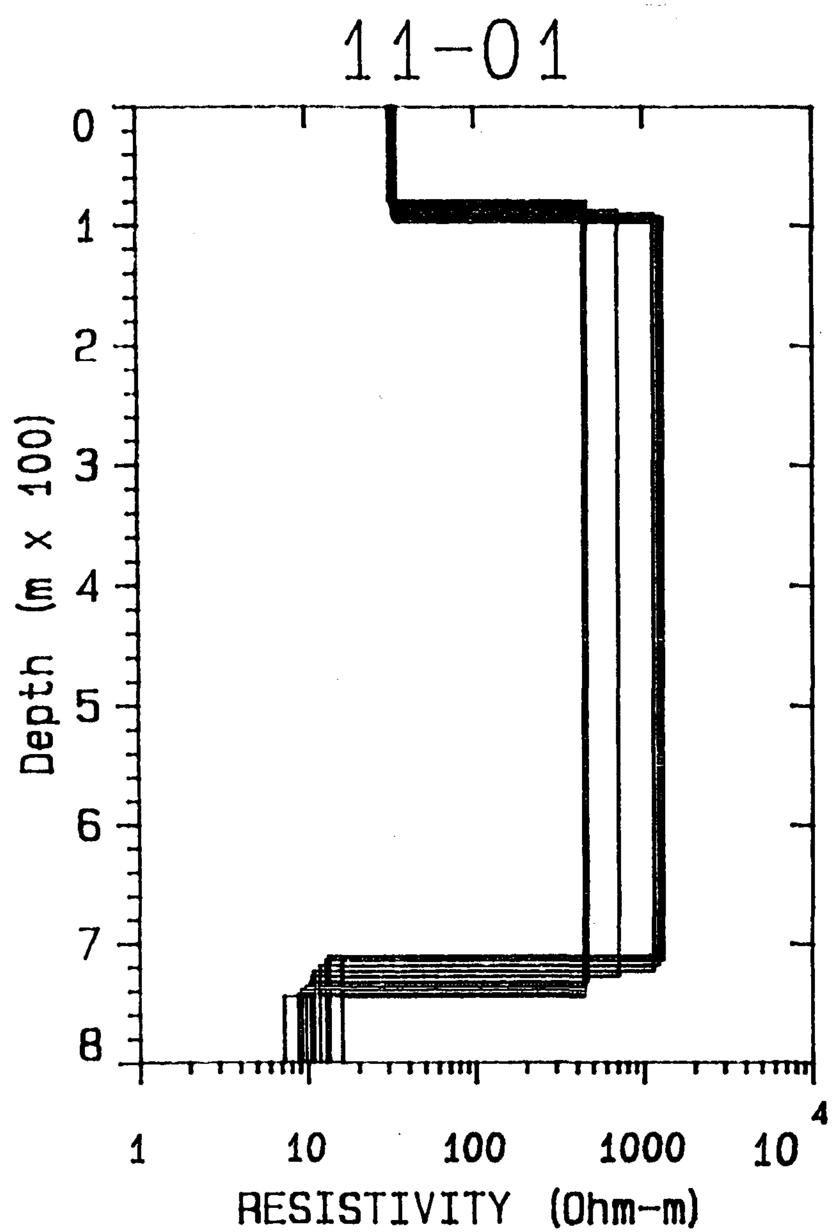


BLACKHAWK GEOSCIENCES, INC.

ORANGE COUNTY LANDFILL
TDEM SOUNDING-DRILLHOLE
COMPARISON

St. Johns River Water Management District

PROJECT NO: 91034 Figure 4-12.3



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

ORANGE COUNTY LANDFILL

SITE 11

St. Johns River Water Management District

PROJECT NO: 91034

Figure 4-12.4

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		25.9	85.0		
32.64	87.9	-62.0	-203.3	2.7	2.7
708.29	640.4	-702.3	-2304.2	0.9	3.6
10.56					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	4.11E+02	4.00E+02	2.678	
2	1.10E-04	2.97E+02	2.92E+02	1.820	
3	1.40E-04	2.11E+02	2.09E+02	0.954	
4	1.77E-04	1.56E+02	1.57E+02	-0.540	
5	2.20E-04	1.23E+02	1.25E+02	-1.016	
6	2.80E-04	9.98E+01	1.01E+02	-1.382	
7	3.55E-04	8.56E+01	8.65E+01	-1.055	
8	4.43E-04	7.77E+01	7.80E+01	-0.431	
9	5.64E-04	7.34E+01	7.29E+01	0.740	
10	7.13E-04	7.20E+01	7.11E+01	1.199	
11	8.81E-04	7.07E+01	7.18E+01	-1.490	
12	1.10E-03	7.40E+01	7.46E+01	-0.841	
13	1.41E-03	8.09E+01	8.06E+01	0.357	
14	1.80E-03	9.11E+01	8.92E+01	2.101	
15	2.22E-03	1.05E+02	9.93E+01	5.391	
16	2.80E-03	1.08E+02	1.12E+02	-3.620	
17	3.55E-03	1.24E+02	1.26E+02	-1.736	
18	4.43E-03	1.35E+02	1.36E+02	-0.703	
19	5.64E-03	1.39E+02	1.39E+02	0.007	
20	7.13E-03	1.33E+02	1.30E+02	1.584	
21	8.81E-03	1.18E+02	1.18E+02	0.671	
22	1.10E-02	1.02E+02	1.03E+02	-0.488	
23	1.41E-02	8.59E+01	8.64E+01	-0.592	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000

CL8Z ARRAY, 23 DATA POINTS, RAMP: 200.0 MICROSEC, DATA: 11-01

ORANGE COUNTY LAND FILL

RMS LOG ERROR: 1.16E-02, ANTILOG YIELDS 2.7148 %

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

ORANGE COUNTY LANDFILL

SITE 11

St. Johns River Management District

PROJECT NO: 91034 **Table 4-12.1**

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00				
P 2	0.00	0.86			
P 3	0.00	-0.04	0.96		
T 1	0.00	-0.02	0.00	1.00	
T 2	0.00	0.01	0.00	0.00	1.00
	P 1	P 2	P 3	T 1	T 2

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	31.098	32.637	34.463
	2	441.161	708.289	1303.037
	3	7.175	10.558	15.788
THICK	1	79.843	87.872	97.893
	2	618.089	640.354	659.821
DEPTH	1	79.843	87.872	97.893
	2	711.182	728.226	745.170

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE
ORANGE COUNTY LANDFILL
SITE 11
St. Johns River Management District

PROJECT NO: 91034 Table 4-12.1

4.13 DESERET RANCH (SITE 12)

Location and Geoelectric Section

The detailed location map of this sounding is shown in Figure 4-13.1. The TDEM data and the inverted geoelectric section is shown in Figure 4-13.2 and consists of a three layer section.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective depth of exploration of the measurement is 9.4 ohm-m, and it is first encountered at an elevation of 1,292 ft below msl. Assuming an average porosity of 25% the chloride concentration below that depth is expected to exceed 3,270 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

The upper 55 ft thick layer with a resistivity of 188 ohm-m is assumed to represent surficial sands and the Hawthorn Group, and the second layer with a resistivity of 26 ohm-m between elevations of 8 ft above msl and 1,292 ft below msl is characteristic of the carbonate rocks of the Upper Floridan aquifer, but also may contain portions of the Hawthorn Group, since it may be more than 55 ft thick here (Toth, 1988). However, since the thickness of the 26 ohm-m is 1,300 ft, the 26 ohm-m value is probably not much influenced by thin clay layers in the Hawthorn Group. Assuming a porosity of 25% a resistivity of 26 ohm-m corresponds to a chloride concentration in excess of 250 mg/l for that entire interval.

Accuracy of Measurement and Interpretation

Figure 4-13.3 shows the evaluation of equivalence of the TDEM sounding at this site, and the inversion table (Table 4-13.1) lists the upper and lower bounds of the parameters of the geoelectric section.

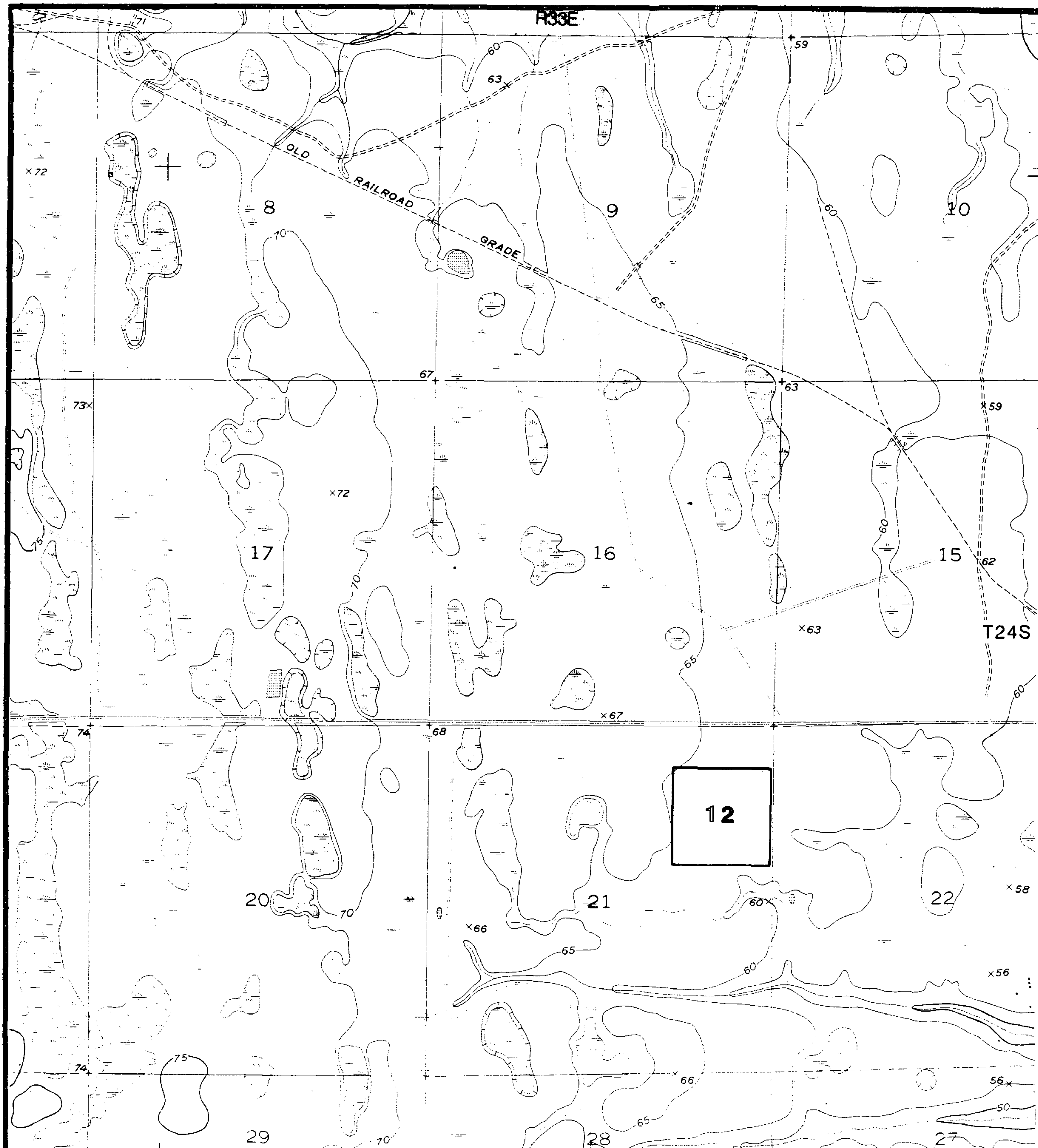
The range of equivalence in determining the depth to saline layer (9.6 ohm-m) is relatively large, ± 15% of total depth or about ± 200 ft for this geoelectric section. The range of equivalence for the resistivity of the second layer, the main section of the Floridan aquifer, is between 25 ohm-m and 27 ohm-m, and for this range of resistivity values chloride concentration in excess of 250 mg/l are predicted for a porosity of 25%.

Summary of Results of TDEM Measurements at Deseret Ranch (Site 12)

From the TDEM measurements at the Deseret Ranch, the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted to occur at an elevation of 1,292 ft below msl, and below that elevation chloride concentrations in excess of 3,270 mg/l are expected. The range of equivalence in determining depth to that layer was relatively large (± 200 ft).

2) In the Floridan aquifer above the interface with saline water at 1,292 ft below msl and below the Hawthorn Group, the chloride concentration of ground water is predicted to be in excess of 250 mg/l.



1	TDEM Sounding

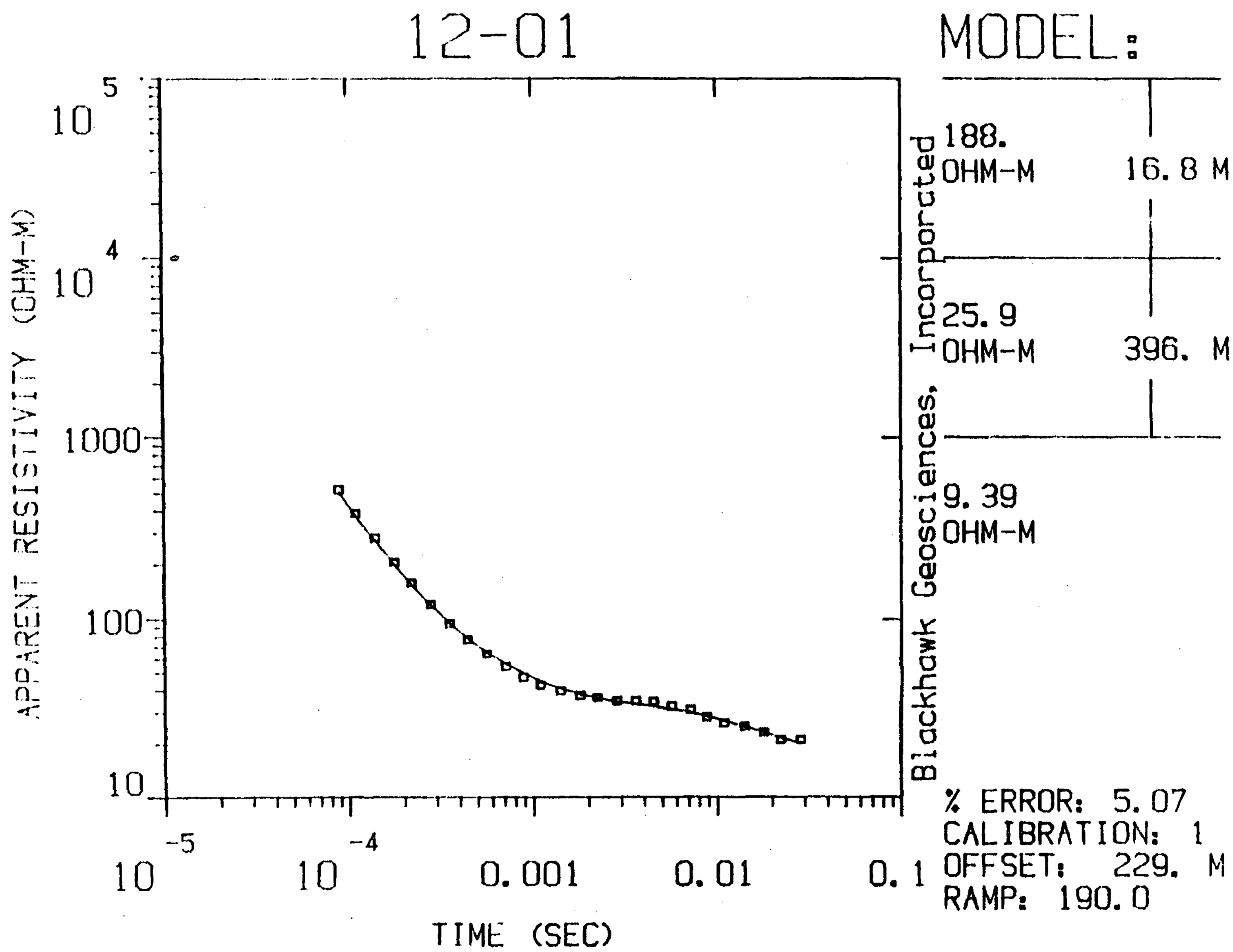
0 2000 4000 Feet

N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 12
DESERET RANCH
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 **Figure 4-13.1**

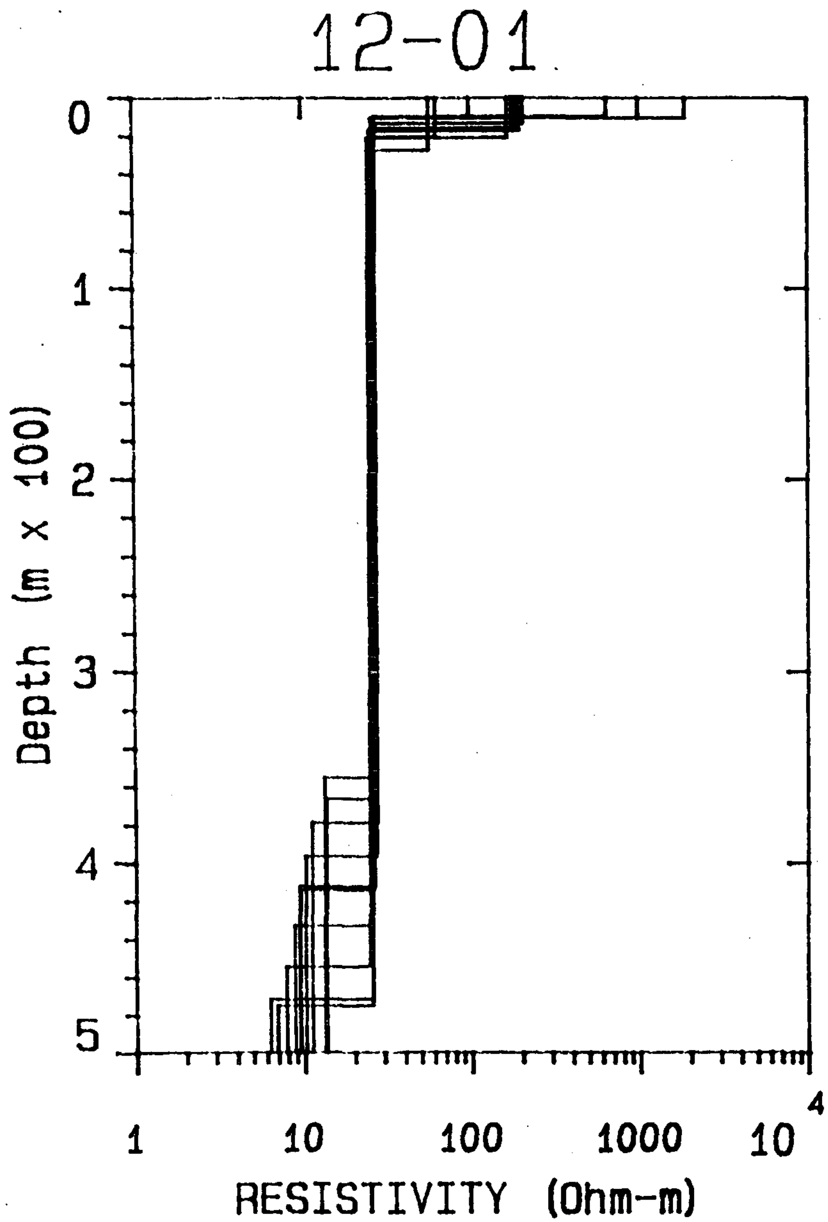


BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

DESERET RANCH
SITE 12
St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-13.2**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

DESERET RANCH

SITE 12

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-13.3**

12-01

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		19.2	63.0		
187.68	16.8	2.4	8.0	0.1	0.1
25.95	396.3	-393.9	-1292.2	15.3	15.4
9.39					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	5.24E+02	5.07E+02	3.352	
2	1.10E-04	3.88E+02	3.75E+02	3.499	
3	1.40E-04	2.81E+02	2.70E+02	4.095	
4	1.77E-04	2.06E+02	2.00E+02	2.957	
5	2.20E-04	1.58E+02	1.54E+02	2.483	
6	2.80E-04	1.20E+02	1.19E+02	1.073	
7	3.55E-04	9.41E+01	9.45E+01	-0.470	
8	4.43E-04	7.69E+01	7.82E+01	-1.627	
9	5.64E-04	6.38E+01	6.53E+01	-2.301	
10	7.13E-04	5.41E+01	5.61E+01	-3.534	
11	8.81E-04	4.73E+01	4.99E+01	-5.333	
12	1.10E-03	4.28E+01	4.51E+01	-5.091	
13	1.41E-03	3.95E+01	4.09E+01	-3.272	
14	1.80E-03	3.72E+01	3.79E+01	-1.826	
15	2.22E-03	3.63E+01	3.61E+01	0.572	
16	2.85E-03	3.48E+01	3.45E+01	1.031	
17	3.60E-03	3.49E+01	3.34E+01	4.500	
18	4.49E-03	3.45E+01	3.24E+01	6.465	
19	5.67E-03	3.26E+01	3.13E+01	3.887	
20	7.16E-03	3.11E+01	3.00E+01	3.686	
21	8.81E-03	2.83E+01	2.86E+01	-1.146	
22	1.10E-02	2.62E+01	2.70E+01	-3.107	
23	1.41E-02	2.50E+01	2.51E+01	-0.007	
24	1.80E-02	2.32E+01	2.32E+01	0.025	
25	2.22E-02	2.11E+01	2.17E+01	-2.455	
26	2.85E-02	2.12E+01	2.01E+01	5.583	

R: 229. X: 0. Y: 229. DL: 457. REQ: 254. CF: 1.0000

CLHZ ARRAY, 26 DATA POINTS, RAMP: 190.0 MICROSEC, DATA: 12-01W

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE
DESERET RANCH
SITE 12

St. Johns River Management District

PROJECT NO: 91034 Table 4-13.1

DESERT RANCH

RMS LOG ERROR: 2.15E-02, ANTILOG YIELDS 5.0655 %

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:

"F" MEANS FIXED PARAMETER

P 1	0.05				
P 2	0.00	1.00			
P 3	0.00	0.00	0.89		
T 1	0.19	0.01	0.01	0.92	
T 2	-0.01	0.00	0.04	0.00	0.98
	P 1	P 2	P 3	T 1	T 2

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	57.660	187.682	1876.823
	2	24.535	25.946	27.277
	3	6.241	9.388	13.529
THICK	1	9.882	16.773	27.735
	2	339.539	396.305	458.229
DEPTH	1	9.882	16.773	27.735
	2	355.784	413.078	475.514

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

DESERET RANCH

SITE 12

St. Johns River Management District

PROJECT NO: 91034

Table 4-13.1

4.14 LAKE MARY (SITE 13)

Location and Geoelectric Section

The detailed location map of this sounding is shown in Figure 4-14.1. The TDEM data and the inverted geoelectric section is shown in Figure 4-14.2, and consists of a three layer section.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective depth of exploration of the measurement is 5.5 ohm-m, and it is first encountered at an elevation of 1,203 ft below msl. Assuming an average porosity of 25% the chloride concentration below that depth is expected to exceed 5,700 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

The upper 123 ft thick layer with a resistivity of 60 ohm-m is assumed to represent surficial sands and the Hawthorn Group, and the second layer with a resistivity of 293 ohm-m between elevations of 78 ft below msl and 1,203 ft below msl is characteristic of the carbonate rocks of the Upper Floridan aquifer. Assuming a porosity of 25% a resistivity of 293 ohm-m corresponds to a chloride concentration less than 250 mg/l for that entire interval. Chloride concentrations less than 250 mg/l for this area are also reported by Tibbals (1990). The 250 mg/l isochlor is expected to coincide with the resistivity boundary between 293 ohm-m and 5.5 ohm-m observed at an elevation of 1,203 ft below msl. A transition zone from ground water with chloride concentrations less than 250 mg/l to in excess of 5,700 mg/l can be expected, so that the isochlor may be some 100 ft above the mapped interface.

Accuracy of Measurement and Interpretation

Figure 4-14.3 shows the evaluation of equivalence of the TDEM sounding at this site, and the inversion table (Table 4-13.1) lists the upper and lower bounds of the parameters of the geoelectric section.

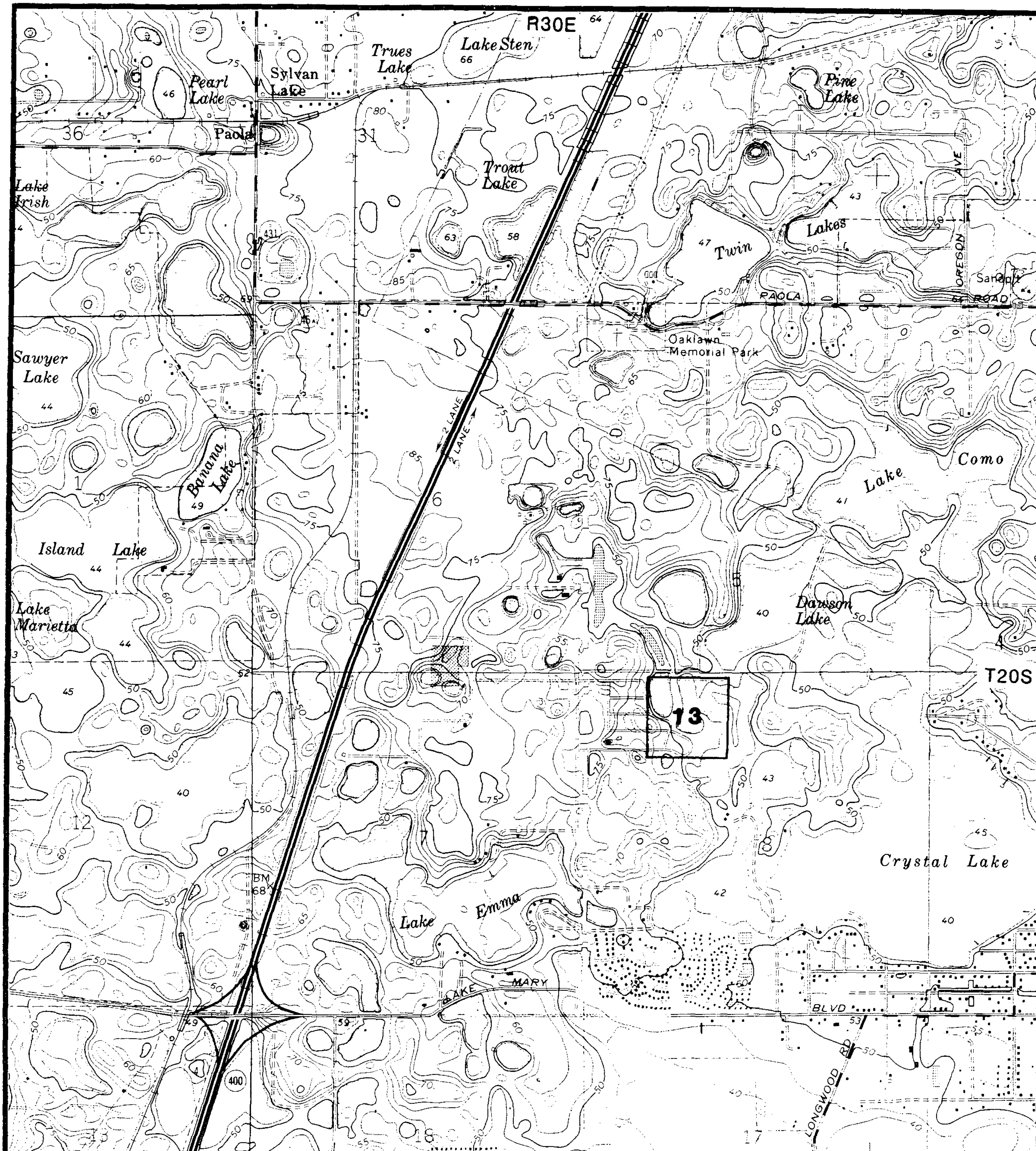
The range of equivalence in determining the depth to the saline layer (5.5 ohm-m) is less than ± 5% of total depth, or about ± 60 ft. The equivalence in the resistivity of the second layer, representing the main section of the Upper Floridan aquifer, is between 244 ohm-m and 387 ohm-m. Assuming a porosity of 25% chloride concentrations less than 250 mg/l are expected for that range of resistivity.

Summary of Results of TDEM Measurements at Lake Mary (Site 13)

From the TDEM measurements at Lake Mary, the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted to occur at an elevation of 1,203 ft below msl, and below that elevation chloride concentrations in excess of 5,700 mg/l are expected.

2) Above the interface with saline water at 1,203 ft below msl and below the Hawthorn Group (78 ft below msl), the chloride concentration of ground water is predicted to be less than 250 mg/l for that entire interval. The depth of occurrence of the 250 mg/l isochlor is expected to approximately coincide with the interface mapped at an elevation of 1,203 ft below msl.



1 TDEM Sounding

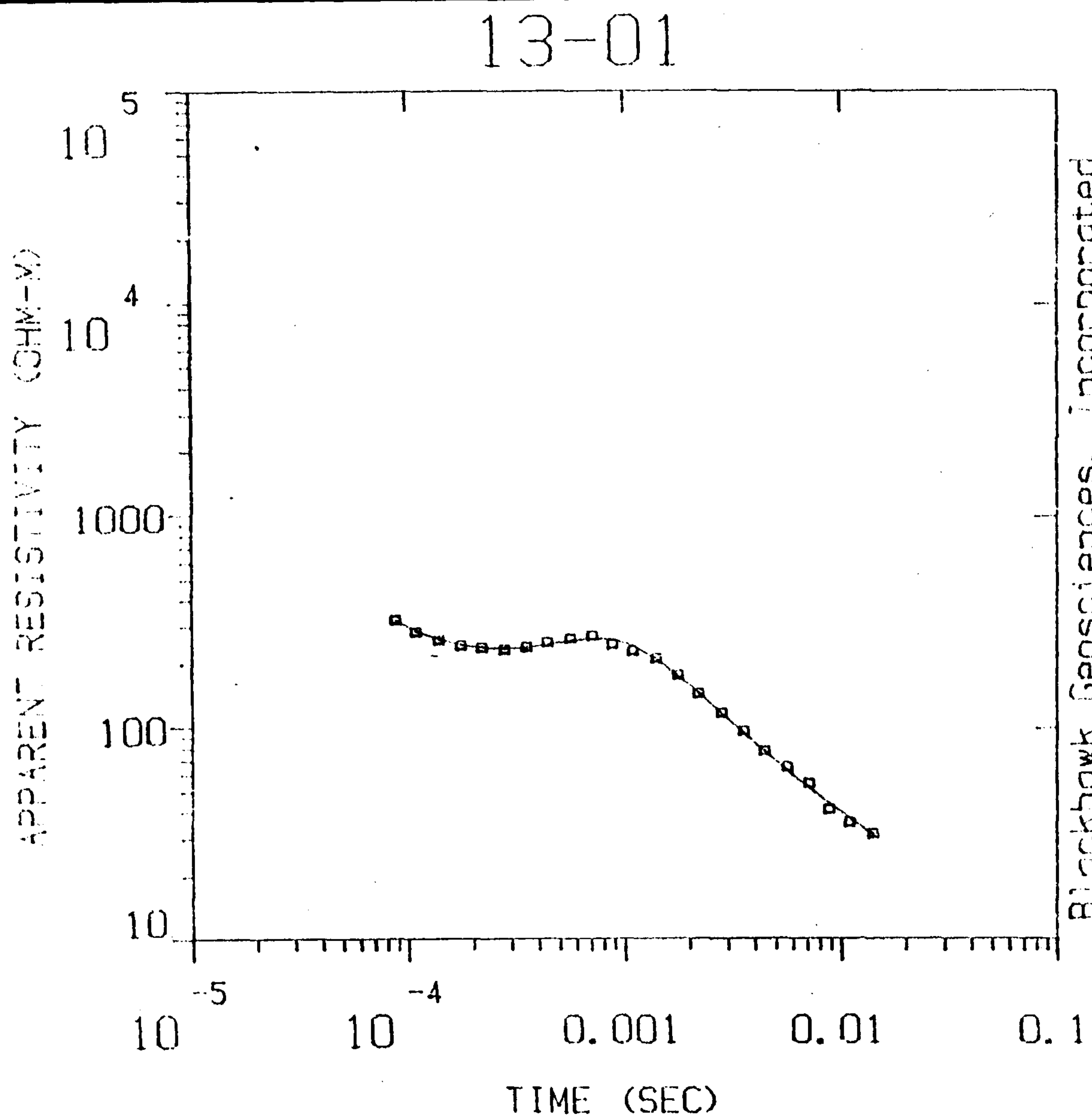
0 2000 4000 Feet

N

BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 13
LAKE MARY
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034 Figure 4-14.1



MODEL:

60.1 OHM-M 37.4 M

293. OHM-M 343. M

5.51 OHM-M

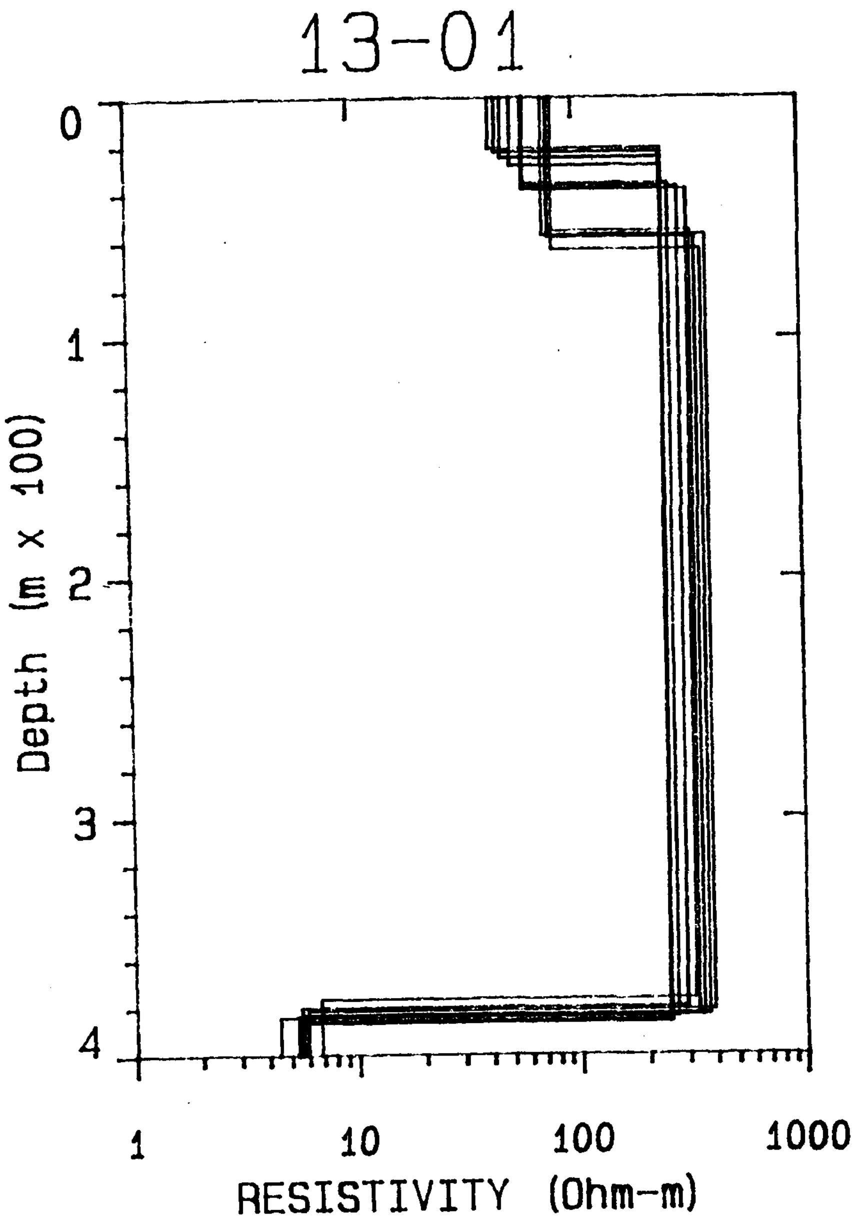
% ERROR: 4.56
CALIBRATION: 1
OFFSET: 160. M
RAMP: 185.0

BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION

LAKE MARY
SITE 13
St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-14.2**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

LAKE MARY

SITE 13

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-14.3**

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		13.7	45.0		
60.06	37.4	-23.7	-77.7	0.6	0.6
292.61	342.9	-366.5	-1202.6	1.2	1.8
5.51					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	3.23E+02	3.19E+02	1.084	
2	1.10E-04	2.84E+02	2.87E+02	-1.014	
3	1.40E-04	2.58E+02	2.61E+02	-0.955	
4	1.77E-04	2.43E+02	2.45E+02	-0.930	
5	2.20E-04	2.37E+02	2.37E+02	-0.017	
6	2.80E-04	2.33E+02	2.35E+02	-0.709	
7	3.55E-04	2.40E+02	2.39E+02	0.537	
8	4.43E-04	2.53E+02	2.47E+02	2.460	
9	5.64E-04	2.64E+02	2.58E+02	2.670	
10	7.13E-04	2.71E+02	2.64E+02	2.610	
11	8.81E-04	2.48E+02	2.61E+02	-5.042	
12	1.10E-03	2.30E+02	2.44E+02	-5.810	
13	1.41E-03	2.13E+02	2.11E+02	0.653	
14	1.78E-03	1.77E+02	1.75E+02	0.978	
15	2.21E-03	1.44E+02	1.45E+02	-0.628	
16	2.83E-03	1.17E+02	1.16E+02	0.834	
17	3.57E-03	9.64E+01	9.41E+01	2.514	
18	4.46E-03	7.79E+01	7.74E+01	0.660	
19	5.67E-03	6.53E+01	6.30E+01	3.708	
20	7.16E-03	5.48E+01	5.20E+01	5.259	
21	8.81E-03	4.14E+01	4.42E+01	-6.422	
22	1.10E-02	3.58E+01	3.76E+01	-4.551	
23	1.41E-02	3.19E+01	3.14E+01	1.397	

R: 160. X: 0. Y: 160. DL: 320. REQ: 178. CF: 1.0000

CLHZ ARRAY, 23 DATA POINTS, RAMP: 185.0 MICROSEC, DATA: 13-01

LAKE MARY

RMS LOG ERROR: 1.94E-02, ANTILOG YIELDS 4.5585 %

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE
LAKE MARY
SITE 13

St. Johns River Management District

PROJECT NO: 91034 Table 4-14.1

LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:

"F" MEANS FIXED PARAMETER

P 1	0.78				
P 2	-0.11	0.85			
P 3	0.00	-0.04	0.92		
T 1	-0.36	-0.24	-0.01	0.37	
T 2	0.04	0.03	0.01	0.07	0.99
	P 1	P 2	P 3	T 1	T 2

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	42.682	60.060	80.696
	2	244.228	292.606	386.935
	3	4.404	5.514	6.755
THICK	1	21.378	37.386	63.826
	2	319.637	342.869	365.184
DEPTH	1	21.378	37.386	63.826
	2	376.715	380.255	386.562

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

LAKE MARY

SITE 13

St. Johns River Management District

PROJECT NO: 91034 Table 4-14.1

4.15 WEKIVA SPRINGS ROAD (SITE 14)

Location and Geoelectric Section

The detailed location map of this sounding is shown in Figure 4-15.1. The TDEM data and the inverted geoelectric section is shown in Figure 4-15.2 and consists of a three layer section.

Depth of Occurrence of Saline Water

The lowest resistivity encountered within the effective depth of exploration of the measurement is 8.7 ohm-m, and it is first encountered at an elevation of 927 ft below msl. Assuming an average porosity of 25% the chloride concentration below that depth is expected to exceed 3,540 mg/l.

Depth of Occurrence of 250 mg/l Isochlor

The upper 142 ft thick layer with a resistivity of 23 ohm-m is assumed to represent surficial sands and the Hawthorn Group, but must also include a portion of the upper carbonate rocks, since Toth et al (1989) reported the top of the Floridan in this area to occur at about 75 ft below mean sea level. The second layer with a resistivity of 49 ohm-m between elevations 108 ft below msl and 927 ft below msl is characteristic of the carbonate rocks of the Upper Floridan aquifer at this site. Assuming a porosity of 25% a resistivity of 49 ohm-m corresponds to a chloride concentration in excess of 250 mg/l for that entire interval. This is not consistent with chloride contents between 100 mg/l and 250 mg/l reported by Toth et al (1989) for this general area.

Reasons for this apparent discrepancy might be:

i) in this area it may not be valid to extrapolate regional information to a local measurement, because of lateral variation; also, changes might have occurred over the five years since the sampling by Toth (1989);

ii) the average porosity of the carbonate rocks may be different than the 25% value assumed;

iii) the chemical composition of ground water may be different from that assumed.

Accuracy of Measurement and Interpretation

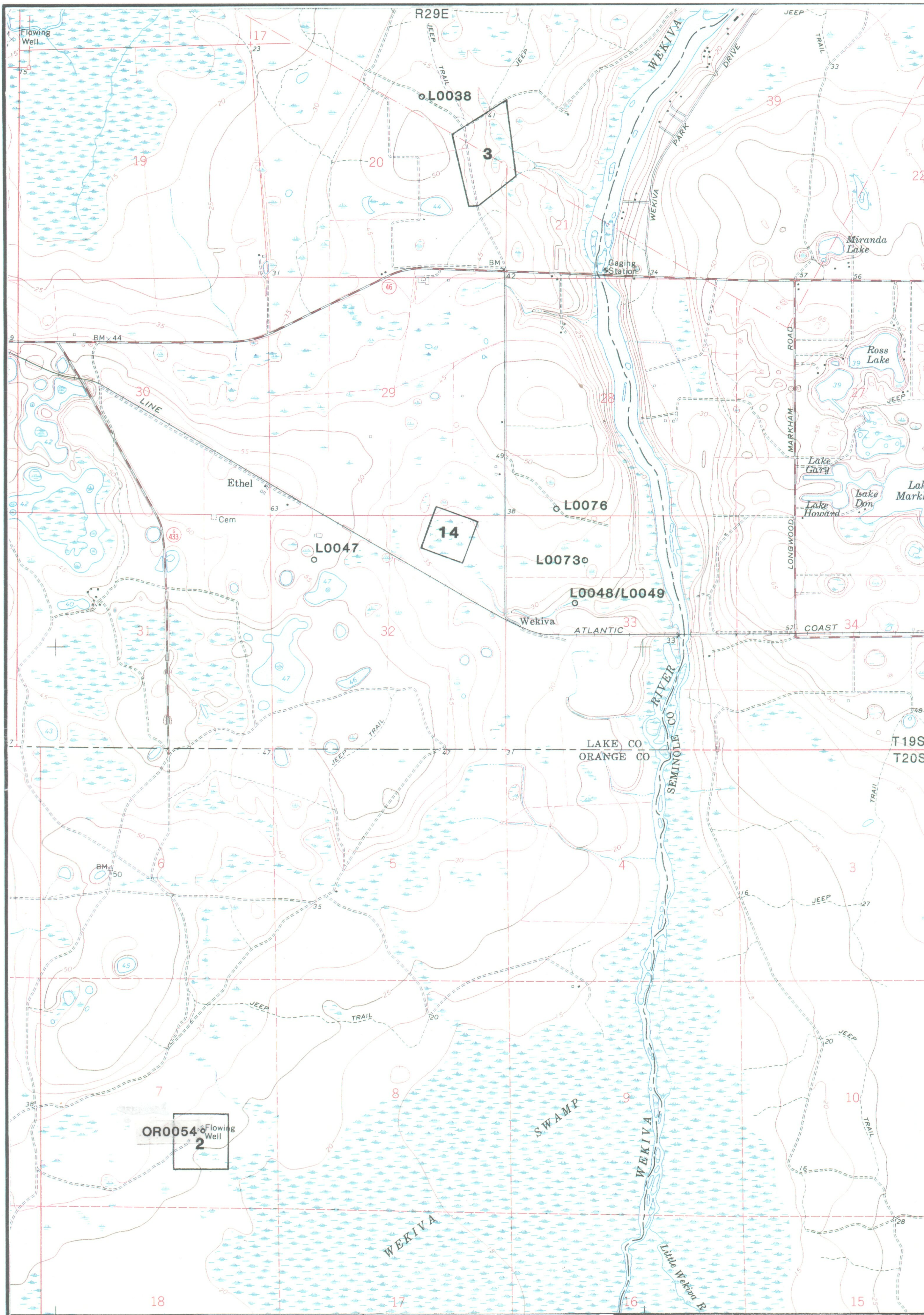
Figure 4-15.3 shows the evaluation of equivalence of the TDEM sounding at this site, and the inversion table (Table 4-14.1) lists the upper and lower bounds of the parameters of the geoelectric section.

The range of equivalence in determining the depth to the saline layer is $\pm$ 5% of total depth, or about $\pm$ 50 ft. The equivalence in the resistivity of the second layer, representing the main section of the Upper Floridan aquifer, is between 45 ohm-m and 55 ohm-m. Assuming a porosity of 25% chloride concentrations greater than 250 mg/l are expected for that range of resistivity.

Summary of Results of TDEM Measurements at Wekiva Springs Road (Site 14)

From the TDEM measurements at Wekiva Springs Road, the following information about water quality was derived:

1) The depth of occurrence of saline water was interpreted to occur at an elevation of 927 ft below msl, and below that elevation chloride concentrations in excess of 3,540 mg/l are expected.

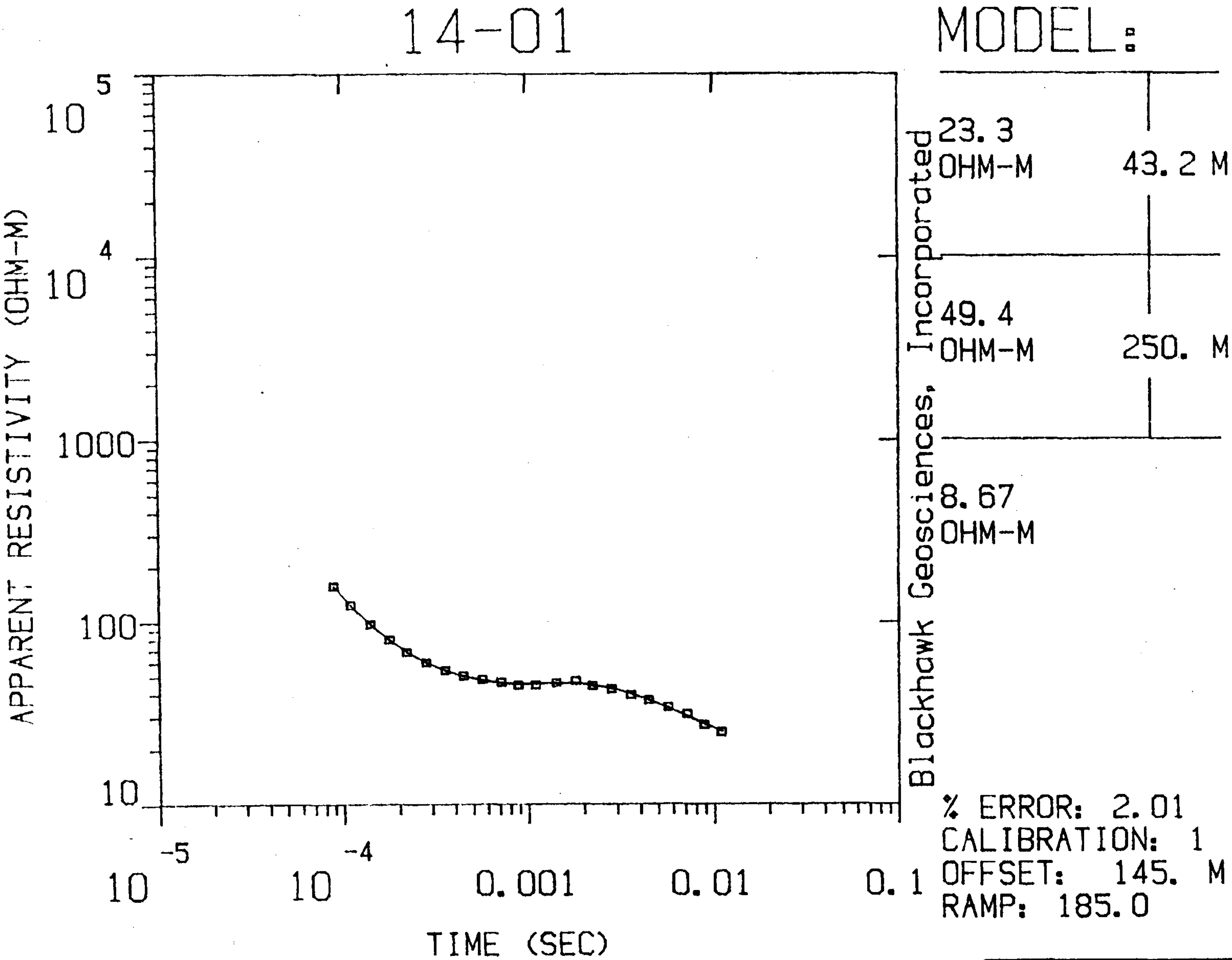


BLACKHAWK GEOSCIENCES, INC.

LOCATION MAP SITE 2,3,& 14
ROCK SPRINGS, WEKIVA RIVER
AND WEKIVA SPRINGS
ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

PROJECT NO: 91034

Figure 4-15.1

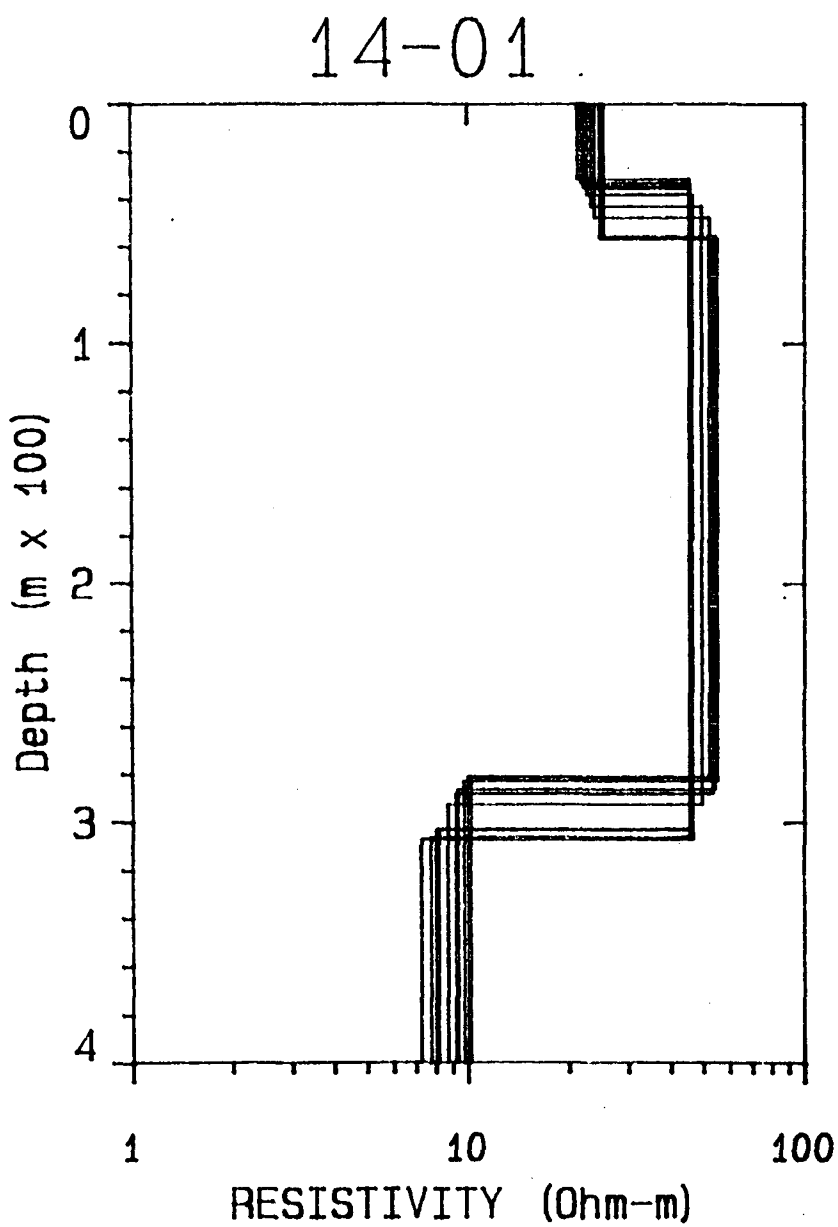


% ERROR: 2.01
CALIBRATION: 1
OFFSET: 145. M
RAMP: 185.0

BLACKHAWK GEOSCIENCES, INC.

MEASURED TDEM APPARENT RESISTIVITY AND 1-D INVERSION
WEKIVA SPRINGS ROAD
SITE 14
St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-15.2**



BLACKHAWK GEOSCIENCES, INC.

EQUIVALENCE IN 1-D INVERSION

WEKIVA SPRINGS ROAD

SITE 14

St. Johns River Water Management District

PROJECT NO: 91034 **Figure 4-15.3**

MODEL: 3 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		10.1	33.0		
23.35	43.2	-33.1	-108.6	1.8	1.8
49.41	249.6	-282.6	-927.3	5.1	6.9
8.67					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-05	1.57E+02	1.57E+02	-0.043	
2	1.10E-04	1.24E+02	1.24E+02	0.532	
3	1.40E-04	9.72E+01	9.72E+01	0.006	
4	1.77E-04	7.98E+01	7.98E+01	-0.003	
5	2.20E-04	6.82E+01	6.86E+01	-0.517	
6	2.80E-04	5.96E+01	5.99E+01	-0.377	
7	3.55E-04	5.40E+01	5.40E+01	-0.023	
8	4.43E-04	5.04E+01	5.02E+01	0.350	
9	5.64E-04	4.81E+01	4.76E+01	1.004	
10	7.13E-04	4.66E+01	4.61E+01	0.939	
11	8.81E-04	4.48E+01	4.56E+01	-1.846	
12	1.10E-03	4.48E+01	4.55E+01	-1.629	
13	1.41E-03	4.60E+01	4.57E+01	0.542	
14	1.80E-03	4.72E+01	4.56E+01	3.425	
15	2.21E-03	4.45E+01	4.49E+01	-0.908	
16	2.80E-03	4.26E+01	4.30E+01	-1.023	
17	3.55E-03	3.95E+01	4.02E+01	-1.720	
18	4.43E-03	3.69E+01	3.71E+01	-0.421	
19	5.64E-03	3.38E+01	3.35E+01	0.927	
20	7.13E-03	3.12E+01	3.02E+01	3.158	
21	8.81E-03	2.72E+01	2.75E+01	-1.241	
22	1.10E-02	2.48E+01	2.50E+01	-0.971	

R: 145. X: 0. Y: 145. DL: 289. REQ: 161. CF: 1.0000

CLHZ ARRAY, 22 DATA POINTS, RAMP: 185.0 MICROSEC, DATA: 14-01

RMS LOG ERROR: 8.63E-03, ANTILOG YIELDS 2.0067 %

LATE TIME PARAMETERS

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

WEKIVA SPRINGS ROAD

SITE 14

St. Johns River Management District

PROJECT NO: 91034 **Table 4-15.1**

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:

"F" MEANS FIXED PARAMETER

P 1	1.00				
P 2	0.00	1.00			
P 3	0.00	0.00	1.00		
T 1	0.00	0.00	0.00	0.99	
T 2	0.00	0.00	0.00	0.00	1.00
	P 1	P 2	P 3	T 1	T 2

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	21.315	23.349	25.339
	2	45.471	49.407	55.172
	3	7.224	8.669	10.183
THICK	1	31.788	43.156	56.815
	2	225.310	249.552	271.430
DEPTH	1	31.788	43.156	56.815
	2	280.972	292.708	307.303

BLACKHAWK GEOSCIENCES, INC.

INVERSION TABLE

WEKIVA SPRINGS ROAD

SITE 14

St. Johns River Management District

PROJECT NO: 91034 Table 4-15.1

2) In the Floridan aquifer above the interface with saline water at 927 ft below msl and below the Hawthorn Group, the chloride concentration of ground water is predicted to be in excess of 250 mg/l. This is not consistent with regional water quality reported by Toth et al (1989) for that area.

5.0 SUMMARY AND CONCLUSIONS

A time domain electromagnetic (TDEM) survey was performed at 14 sites in the St. Johns River Water Management District during the month of August 1991. Several aspects of the survey are summarized below.

From a TDEM survey the resistivity layering (geoelectric section) of the subsurface is derived. To correlate the resistivity values measured to water quality certain manipulations and assumptions were made, such as:

(i) two factors mainly influence the formation resistivity of the Floridan aquifer - concentration of dissolved solids and porosity. These two factors cannot be separated from surface electrical measurements. To derive water quality a realistic range of porosity for the Upper Floridan aquifer needed to be assumed. A porosity of 25% was consistently used for the carbonate rocks of the Upper Floridan aquifer at all 14 sites (NW Florida Water Management District, 1983).

(ii) the relation between formational resistivity and chloride content also is influenced by chemical composition of ground water. In correlating resistivity to chloride content the relationship between these two parameters observed by Kwader (1986) in Seminole County, was assumed to be valid throughout the SJRWMD.

Resistivity values not only depend on ionic concentration and porosity, but also on lithology, - particularly clay content. The lithology of the carbonate rocks of the Upper Floridan are expected to be consistent, but major variation in clay content for the Hawthorn Group and younger sediments overlaying the Floridan aquifer may exist. For that reason water quality was inferred for the carbonate rocks below the Hawthorn Group and younger sediments.

At some sites no resistivity boundary is obtained at the interface between the Hawthorn Group and the carbonate rocks of the Floridan aquifer, so that the upper resistivity layer derived includes surficial sediments, the Hawthorn Group, and parts of the rocks of the Upper Floridan. In those situations it is difficult to evaluate the influence of clay layers on the resistivity value measured, and at some sites no information about chloride concentration can be inferred.

<u>Determining the Depth of the Interface Between Fresh Water and Ground Water of High Chloride Concentration (greater than 1,000 mg/l</u>

Ground water with a chloride content greater than 1,000 mg/l is characterized in the Floridan aquifer by resistivities less than 28 ohm-m when the aquifer has a porosity of about 25%. A layer with a resistivity less than 28 ohm-m was detected at 13 of the 14 sites at depths varying from about 200 ft to 2,400 ft. It was not detected at the site in the Wekiva Springs State Park (Site 1). For this site computer modeling studies showed that the minimum depth a layer with resistivities characteristic of chloride concentrations greater than 1,000 mg/l (28 ohm-m) could occur was about 1,800 ft.

At one of the 14 sites, Astronaut High School, a nearby well penetrated the interface of high chloride concentrations. The interpretation of the depth to the interface derived from the TDEM data and that observed in the well closely correspond. At other sites the depth to the interface was consistent with regional information, such as that published by Tibbals (1990).

Water Quality in the Upper Floridan Aquifer and Depth of Occurrence of 250 mg/l Isochlor

Deriving water quality in the Upper Floridan aquifer above the interface with ground water of high salinity (greater than 1,000 mg/l chloride) at several sites is complicated by the possibility that the average resistivity measured may be influenced by clay stringers in the Hawthorn Group, and that influence must be evaluated for each site. This complication arises from the fact that sometimes no resistivity contrast is observed at the interface between the Hawthorn Group and Upper Floridan aquifer.

Assuming a porosity of 25% and validity of the relation between chloride concentration and formation resistivity, ground water with chloride concentrations less than 250 mg/l are expected at formation resistivities greater than 80 ohm-m. At some sites formation resistivities in the carbonate rocks of the Upper Floridan aquifer were below 80 ohm-m for the entire depth interval above the interface with highly saline water. In those cases chloride concentrations greater than 250 mg/l are expected for the entire Upper Floridan aquifer. At other sites resistivities greater than 80 ohm-m were determined for the upper portion of the aquifer. Often a boundary was observed between resistivities greater than 80 ohm-m and much less than 80 ohm-m at some depths. In those situations the depth (or elevation) of the resistivity boundary was taken to correspond with the depth of occurrence of the 250 mg/l isochlor. It is common in aquifers to have a transition zone over which water quality gradually increases with depth. Such transition zones are not mapped with TDEM, and the 250 mg/l isochlor likely occurs some distance above the resistivity boundary.

6.0 REFERENCES

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