# PROCEEDINGS
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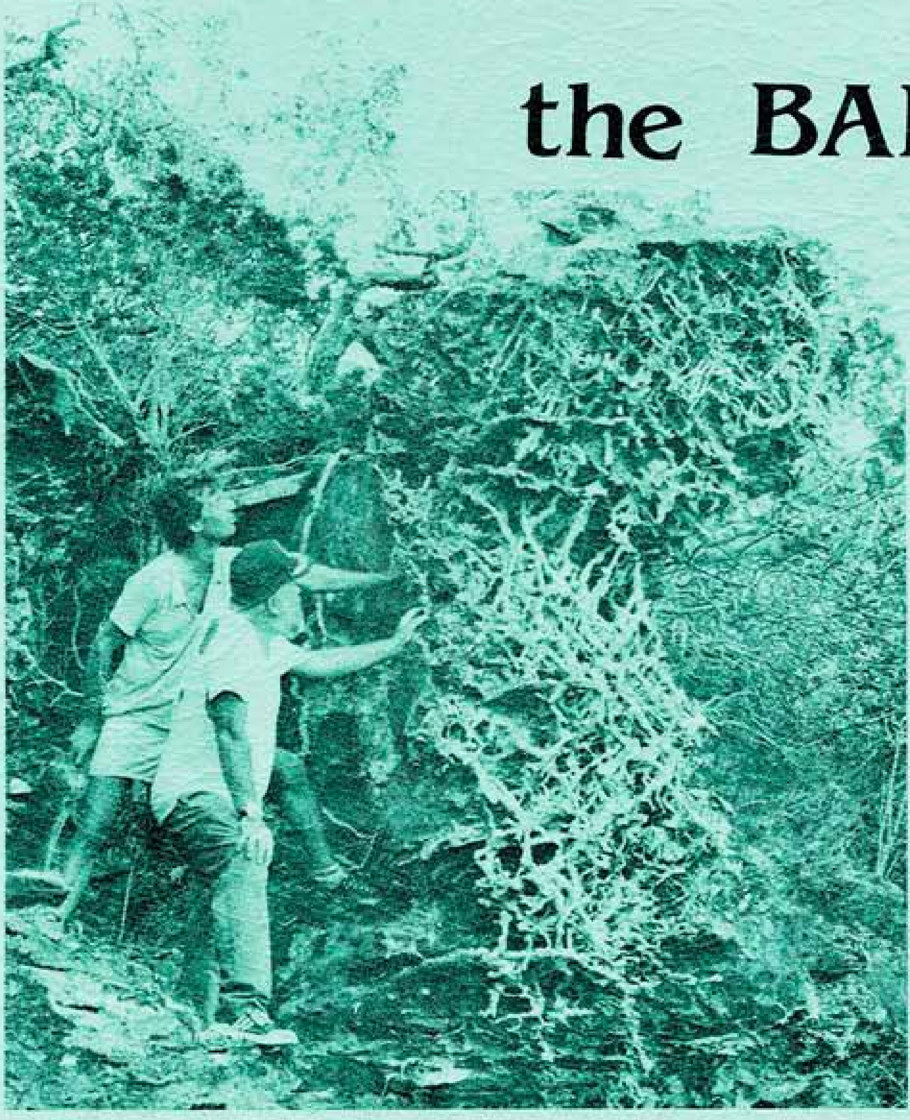

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*CCFL Bahamian Field Station*

# A RESISTIVITY SURVEY OF SANDY POINT
# SAN SALVADOR, BAHAMAS

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Abstract

An electrical resistivity sounding survey of Sandy Point, San Salvador, Bahamas, was conducted December 1982/January 1983 in order to explore and map local ground water resources. The survey utilized the Schlumberger electrode configuration with a Soiltest R-60 apparatus. Twenty-eight field stations were established within the one square mile study area. The field data were analysed digitally using a USGS resistivity inversion computer program based on the Dar Zarouk algorithm.

The results indicate a probably major fresh water Ghyben-Herzberg lens beneath the topographic high of the southern portion of Sandy Point and extending along the northwestern coastal ridge beyond the northern limit of the study area. Maximum thickness of this lens ranges from approximately 40 to 100 feet. A lesser fresh water lobe extends along the southern part of the southeastern coastal ridge. Most of the interior and northeastern portions of Sandy Point appear to lack fresh groundwater. Possible perched water tables are indicated by irregularities in many of the electrical sounding curves in the peripheral hills of Sandy Point.

## Introduction

The fresh ground water system of San Salvador is not very well known. Of specific interest are the fresh water resources in the Sandy Point area in view of their importance to the potential development of Columbus Landings Subdivision. A previous engineering survey, using chemical and electrical conductivity measurements in test wells (Greene and Associates, 1972), located only limited fresh water resources in the northern part of the interior Sandy Point region. No test wells were drilled in the peripheral hills of Sandy Point. At some later time a substantial fresh water lens near the west coast, north of

Grotto Bay, was found and tapped by a production well field. The purpose of our survey was to estimate the total extent of fresh water resources throughout all of Sandy Point using the electrical resistivity method.

San Salvador is particularly well suited for electrical surveys because of its relatively pure carbonate geology. Carbonates and other clean rocks are essentially electrical insulators. Such rocks conduct electricity by virtue of the conductivity of their pore fluids. Hence the electrical resistivity $\rho_R$ of saturated carbonate rocks is a function of their porosity $\Phi$ and pore water resistivity $\rho_W$. According to the basic Archie relationship

$$\rho_R = \frac{\rho_W}{\phi^2}$$

Potable water, as defined by the World Health Organization, has a maximum chloride concentration of 600 ppm. This corresponds to a total salinity of approximately 1000 ppm or more, depending on the other ions present. In this study a total salinity of 1000 ppm was taken as the upper limit for potable water.

At 25 C, according to Nomogram Gen-9 published by Schlumberger (1984), the minimum resistivity of fresh water (1000 ppm salinity) is 16.4 Ω-ft and that of sea water (35,000 ppm salinity)is 0.6 Ω-ft. The corresponding (according to the basic Archie formula) rock resistivities at different porosities are shown in Table 1.

Two facts are immediately clear:

1. There is a tremendous resistivity contrast between salt water and fresh water rock of similar porosity.
2. Low porosity sea water rock has similar resistivities as high porosity fresh water rock. These two possibilities cannot be distinguished by resistivity alone.

Most rock formations on San Salvador are characterized by high porosities in the range of 10-30% (e.g. Titus, 1980). In this range there is not resisitivity overlap. If the average porosity of the aquifers involved is somewhat less than 25%, then the average resistivity of a salt water aquifer on San Salvador is on the order of 10Ω-ft, and that of fresh water aquifer is 300 Ω-ft or greater. These arbitrary resistivity values were used in this survey to delineate fresh water aquifers on Sandy Point.

TABLE 1

Rock Resistivities at 25°C

| Porosity (%) | Sea Water Limestone (Ω-ft) | Fresh Water Limestone (Ω-ft) |
|---|---|---|
| 3 | 670 | 18000 |
| 5 | 240 | 6600 |
| 10 | 60 | 1640 |
| 20 | 15 | 410 |
| 25 | 10 | 260 |
| 30 | 7 | 180 |

The values for fresh water limestone are minimum values.

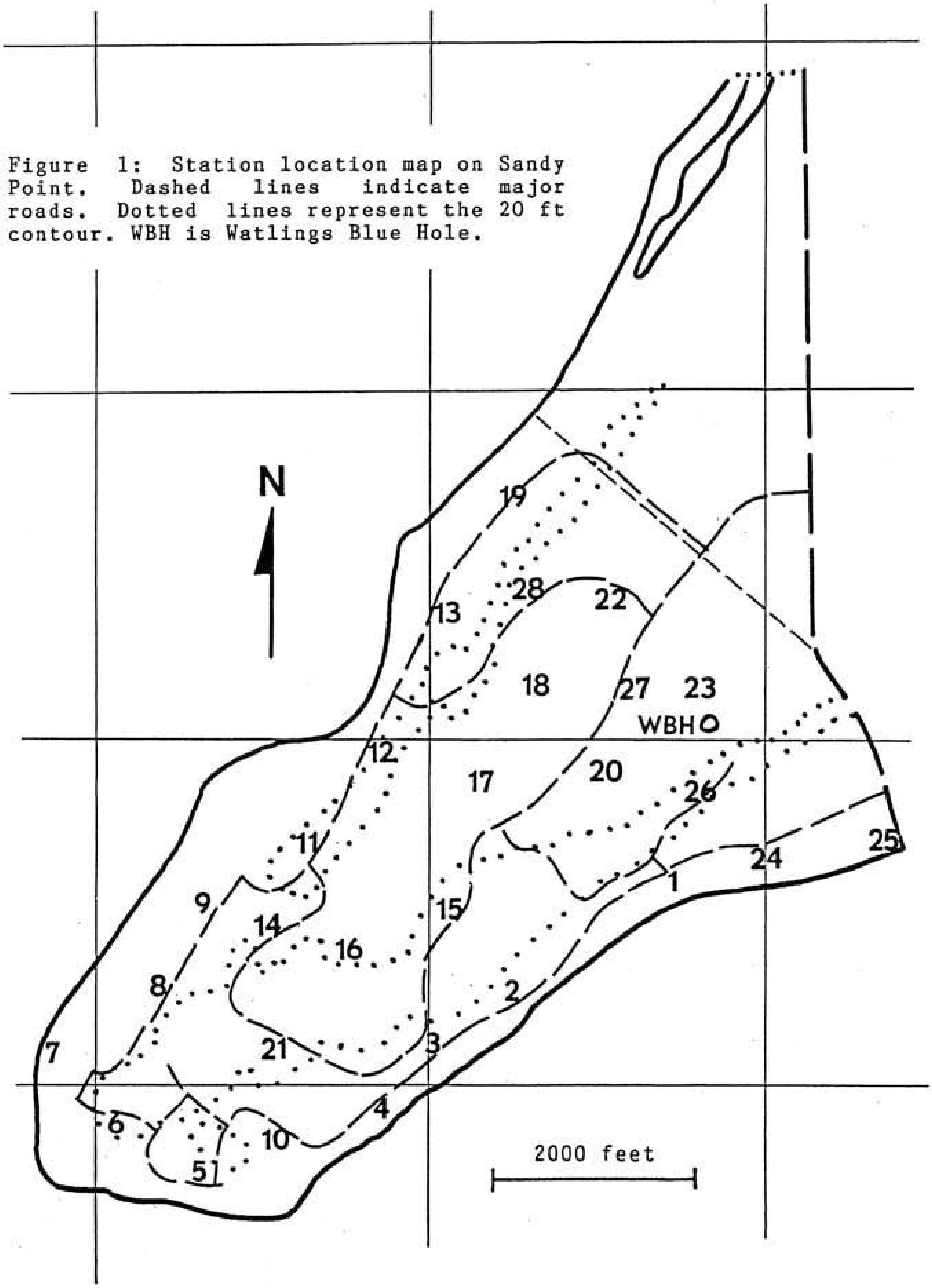


Figure 1: Station location map on Sandy Point. Dashed lines indicate major roads. Dotted lines represent the 20 ft contour. WBH is Watlings Blue Hole.

On oceanic islands such as San Salvador, the fresh ground water lens generally floats on sea water saturated rocks in accordance with the Ghyben-Herzberg relationship, such that the ratio of water table elevation to fresh water lens thickness is approximately 1:40. In cases of a substantial saline transition zone at the bottom of the fresh water lens, this ratio may approach 1:20 (Bugg and Lloyd, 1976). As a result, accurate mapping of a fresh ground water lens can be accomplished by determining the depth of the fresh water-salt water interface. This is readily accomplished with the electrical resistivity method in view of the large, unmistakable resistivity contrast between fresh water and salt water saturated rocks.

## Procedures

Our study utilized the Schlumberger electrode configuration with a Soiltest R-60 resistivity apparatus. Electrical sounding curves were constructed based on current electrode half spacings (L) ranging from 5 to 500 feet with 6 points per decade. Sounding curve inversion was accomplished with the USGS computer program INVERSE which utilized a modified Dar Zarouk algorithm (Zohdy, 1975). Some model parameters, such as number of layers expected and resistivity of the lowest layer (10 $\Omega$-ft), were specified a priori.

Twenty-eight field stations were established at convenient sites along road sides throughout the one square mile study area (Fig. 1). The field survey was conducted during a two week period in December 1982/January 1983. Station elevations

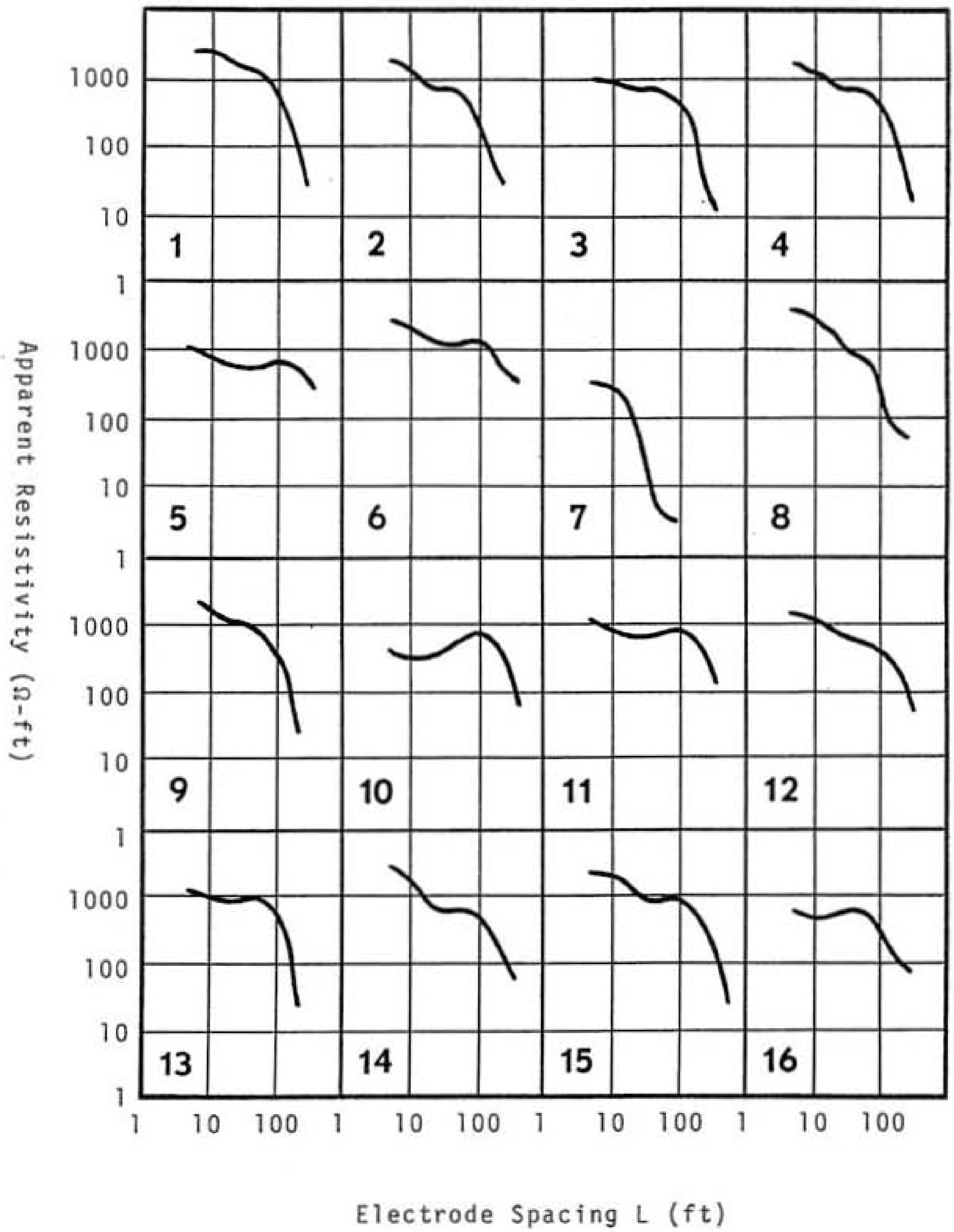


Figure 2: Field sounding curves for stations 1 through 28. Discussion in text.

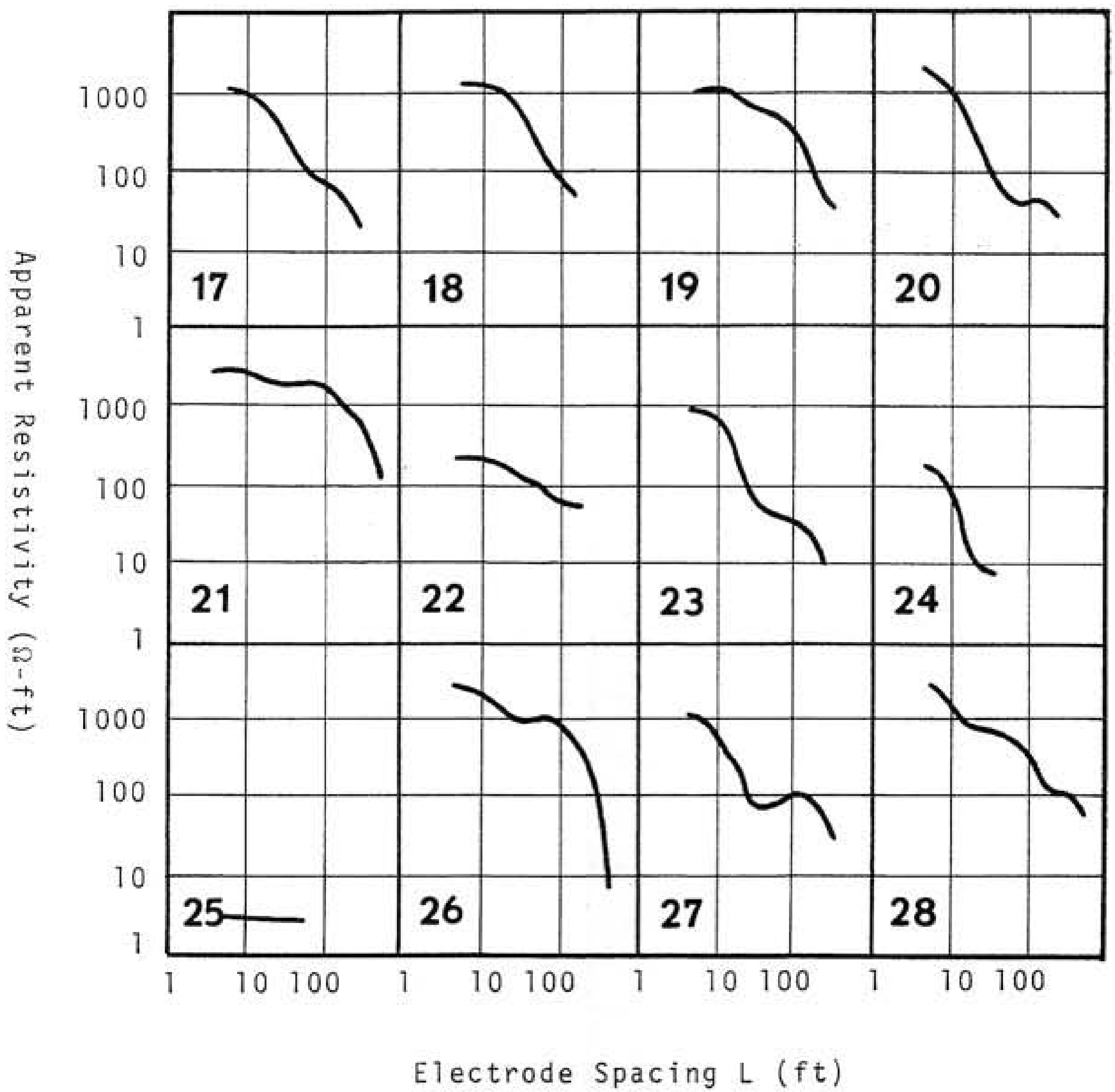


Figure 2 (con't)

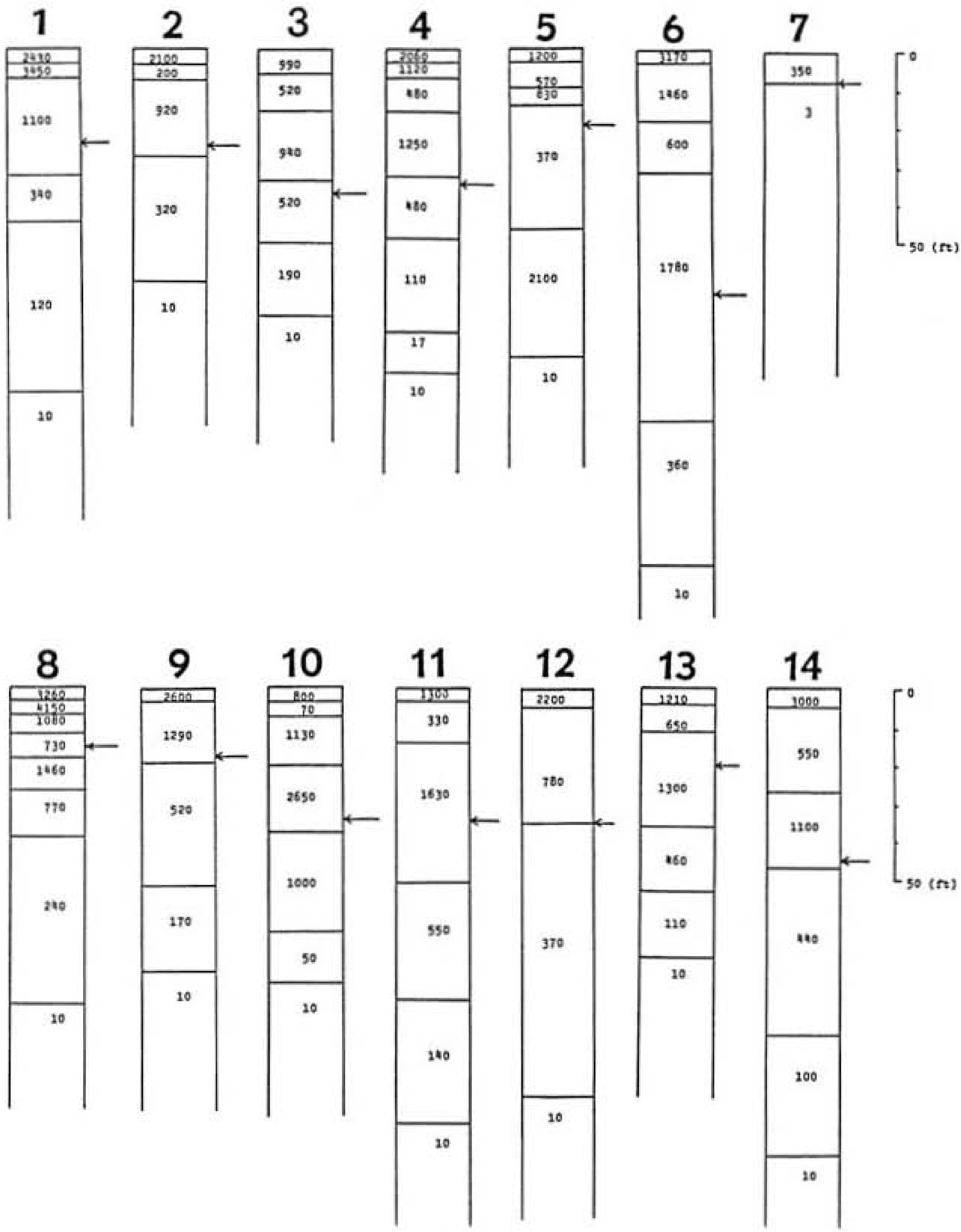


Figure 3: Computer generated resistivity layer models based on field sounding curves. Arrows indicate sealevel. Discussion in text.

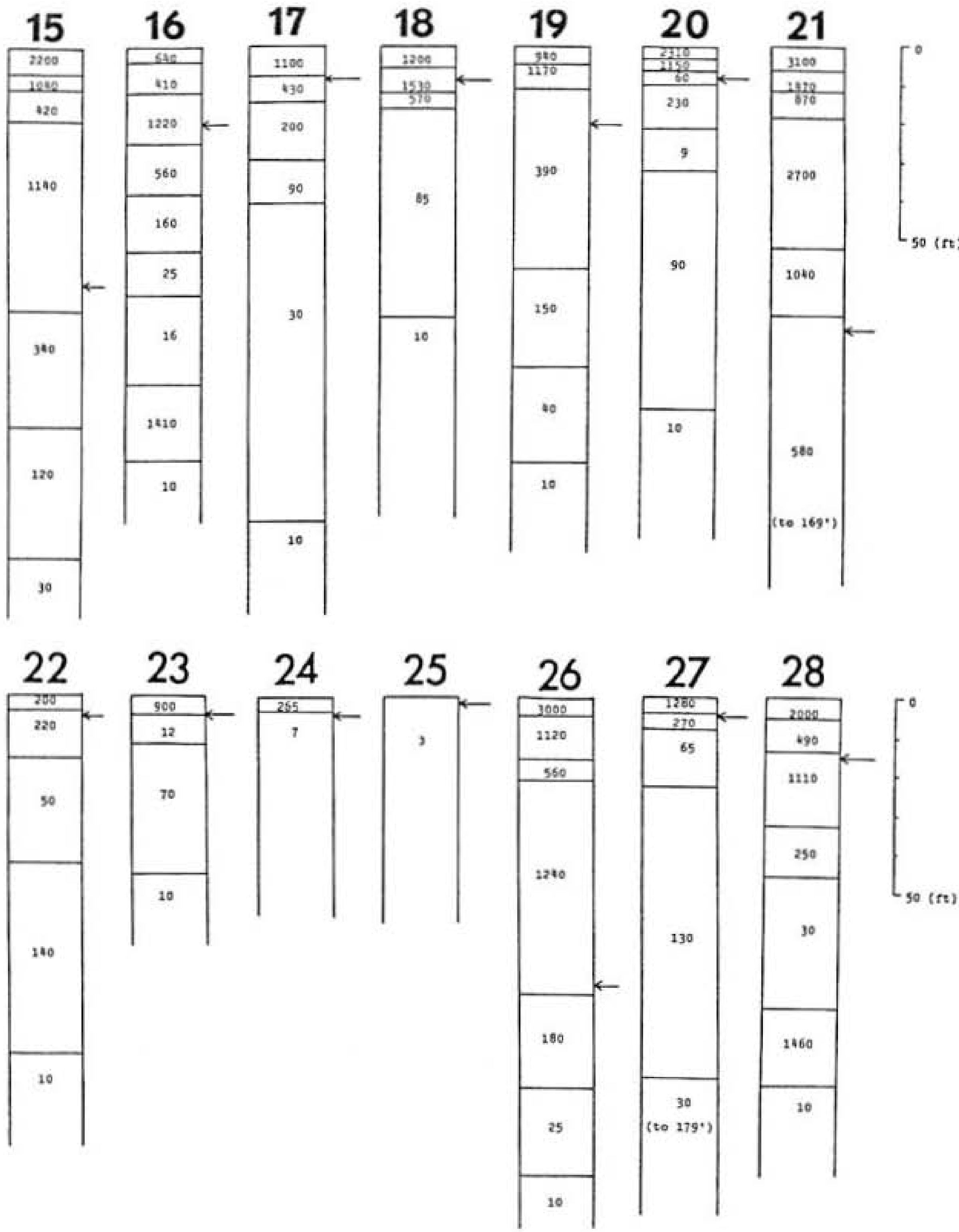


Figure 3 (con't)

were estimated based on the topographic map of San Salvador (Sheet 1) published in 1972 by the Bahamas Government. Maximum station elevation error is estimated to be ± 5 feet.

## Results and Interpretation

The resulting 28 sounding curves are shown in Fig. 2, and the corresponding resistivity layer models in Fig. 3. A Ghyben-Herzberg fresh water lens with or without a brackish transition zone is indicated at all except stations 7 (beach), 20 (interior basin), 22 (interior basin), 23 (interior basin), 24 (coastal lowland), 25 (beach), 36 (ridge near Watling's Castle), and 27 (interior basin). Elevated zones of anomalously low resistivity, possibly indicating perched water tables atop paleosols, are seen at stations 2, 3, 4, 5, 6, 10, 11, 13, 14, 15, 16, 21, and 26. Alternately, some of these zones may represent marl or clay bearing layers, or downward migrating rain water after heavy downpours. Unusually high resistivity layers below sealevel at staions 5, 6, 8, 16, 20, 22, 23, 27, 28 and above sea level at stations 6, 10, and 21 may be caused by zones of low porosity (micrite?) and by dry cave horizons, respectively. Wet cave horizons below sea level should represent layers of unusually low resistivity. Such layers may be present beneath stations 7, 20, 22, 23, 24, 25, 27, and 28. Alternately, the anomalously low resistivity of 3 Ω-ft at the beach stations (7,25) may be due to exceptionally high beach sand porosity (over 40%), higher beach temperatures, current deflection by the ocean, or a combination of these factors.

TABLE 2

Gyben-Herzberg Lens Parameters

| Station | Elevation (ft.) | Lens Bottom Depth (ft.) | Water Table Elevation (ft.) | Lens Thickness (ft.) |
|---|---|---|---|---|
| 1 | 25 | -21 T | 1.1 | 22 |
| 2 | 25 | -37 | 0.9 | 38 |
| 3 | 39 | -13 T | 0.7 | 14 |
| 4 | 35 | -14 T | 0.7 | 15 |
| 5 | 20 | -61 | 1.6 | 63 |
| 6 | 65 | -71 | 1.8 | 73 |
| 7 | 8 | | | |
| 8 | 16 | -24 T | 1.3 | 25 |
| 9 | 18 | -34 T | 1.8 | 36 |
| 10 | 35 | -30 | 0.8 | 31 |
| 11 | 35 | -47 T | 2.5 | 49 |
| 12 | 35 | -73 | 1.9 | 75 |
| 13 | 20 | -33 T | 1.7 | 35 |
| 14 | 45 | -46 T | 2.4 | 48 |
| 15 | 63 | -38 T | 2.0 | 40 |
| 16 | 20 | -18 T | 0.9 | 19 |
| 17 | 8 | - 6 | 0.2 | 6 |
| 18 | 8 | - 7 | 0.4 | 7 |
| 19 | 20 | | | |
| 20 | 8 | | | |
| 21 | 74 | -95 | 2.4 | 97 |
| 22 | 5 | | | |
| 23 | 5 | | | |
| 24 | 5 | | | |
| 25 | 0 | | | |
| 26 | 75 | | | |
| 27 | 5 | | | |
| 28 | 15 | -18 T | 0.9 | 19 |

Note: T indicates brakish transition zone

Assuming that the transition from 300 Ω-ft to 10 Ω-ft below sea level represents the bottom of a Ghyben-Herzberg fresh water lens, then the top of that lens must be above sealevel at an elevation of approximately 1/39 of the lens bottom depth (or 1/19 if a transition zone is present). The resulting fresh water lens parameters are listed in Table 2, and the corresponding fresh water isopach map is shown in Fig. 4. In view of the uncertainty in station elevation, the resulting values are uncertain by at least ± 5 feet.

Fig. 5 shows selected profiles of the inferred ground water lens on Sandy Point. In this figure, layers with resistivities above 300 Ω-ft but below that of neighboring layers are shaded black and may represent fresh water, including possible perched water tables. Layers with resistivities between 100 and 300 Ω-ft are stippled and may represent brackish water, and layers below sealevel with unusually high resistivities are designated by the letter H. Regions a, b, c, and d represent the SE side, S point, NW side and interior of Sandy Point, respectively.

## Conclusions

There appears to be a major fresh water lens with maximum thickness of nearly 100 feet beneath the southern hills of Sandy Point. This lens extends northward along the western ridge beyond the survey area with an approximate maximum thickness of 40-50 feet. A lesser fresh water lobe extends beneath the eastern ridge of Sandy Point to the vicinity of station 1.

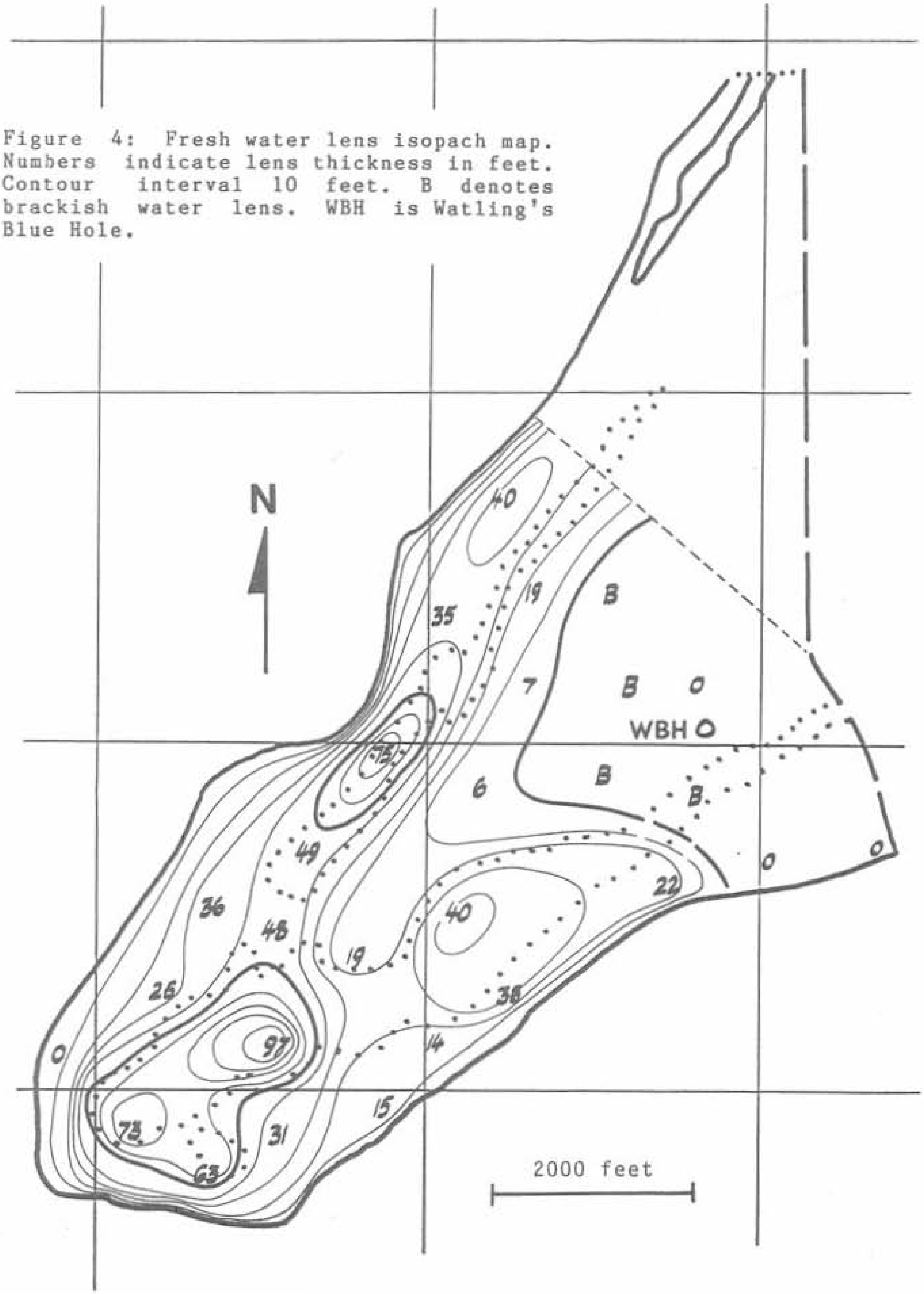


Figure 4: Fresh water lens isopach map. Numbers indicate lens thickness in feet. Contour interval 10 feet. B denotes brackish water lens. WBH is Watling's Blue Hole.

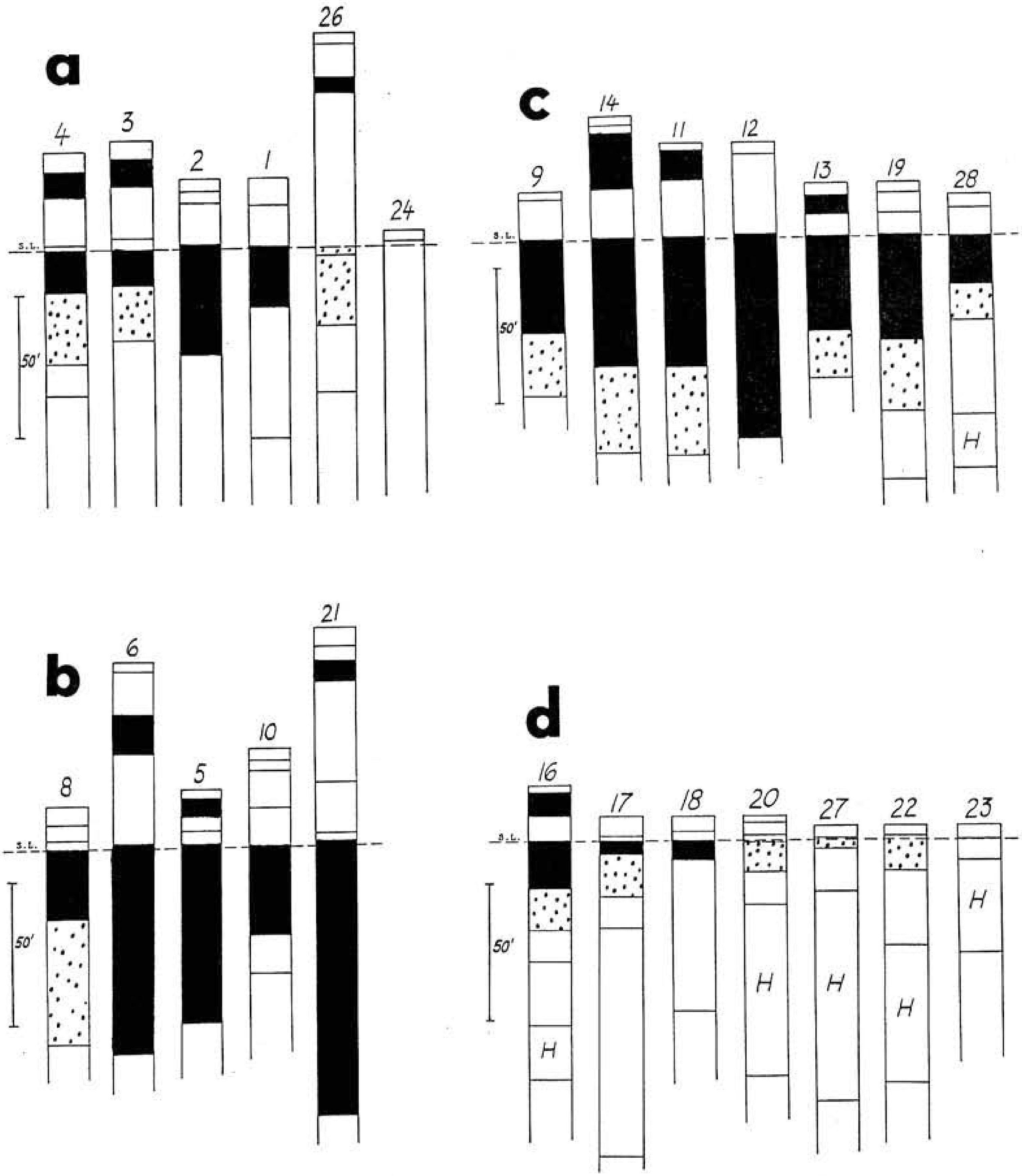


Figure 5: Selected profiles of ground water lens on Sandy Point. Discussion in text.

Beyond station 1, the lens is brackish or totally absent; presumably disrupted by tidal pumping associated with Watling's Blue Hole. Similarly, as already determined by Greene and Associates (1972), no significant fresh water reserves occur in the interior of Sandy Point. The thin fresh water layer indicated at stations 17 and 18, if real, may be a seasonal phenomenon, considering that our survey was conducted just after the rainy season.

The western extension of the fresh water lens north of Grotto Bay is confirmed by the existing well field. Model lens resistivity values in this area are 390 and 460 Ω-ft (stations 19 and 13). A well drilled at a home site next to station 26 encountered only brackish water. Our survey results show a corresponding resistivity value of 180 Ω-ft. Evidently, the choice of 300 Ω-ft or greater for the resistivity of fresh water aquifers on San Salvador is a reasonable one.

Acknowledgements

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