United States Department of Agriculture

Soil Conservation Service

Northeast NTC
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Subject: EM Survey at Mormon Mesa, NV Date: September 14, 1989

To: Dr. Carolyn Olson
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Looking at the data and the assumed relationships, I regret that we didn't have more time at Mormon Mesa. Relationships do exist, but substantiation will require additional field work. I calibrated the EM meter in the vertical dipole position and feel that the horizontal measurements are in error. Therefore, I will not discuss horizontal measurements any further. Remember relative values are often more important that the actual values.

An electrical conductivity survey, using electromagnetic induction (EM) methods, was carried out at three sites near Mesquite, Nevada. The purpose of this investigation was to map variations in terrain conductivity with landscape position. Difference in the electromagnetic conductivity of soils have been related to changes in volumetric water content, and the amount and type of dissolved salts and clays (McNeil, 1980)*. It was assumed that changes in electromagnetic conductivity could be related to differences in soil properties and could be used to map and characterize soils.

A Geonic Limited EM-38 electromagnetic induction soil conductivity meter was made available for this study by the North Dakota Soil Conservation Committee. With the EM-38 meter placed on the surface and orientated in a vertical and horizontal dipole positions, profile measurements of the electromagnetic conductivity were made to depths of 1.5 and 0.75 meters respectively. However, this report is restricted to a discussion of the relationships observed in the vertical dipole position.

Vertical EM conductivity readings were made along transects on Mormon Mesa, at an intermediate site along the northern flank of Mormon Mesa, and near the Virgin River. The three sites were significantly different in terms of electromagnetic conductivity. ANOVA revealed a significant difference (.001 level) in the electromagnetic conductivities among the sites. Generally, electromagnetic conductivity decreased with elevation ($r = -0.655$). The average values changed with dominant soil type from Typic Paleorthids (7.78) to Typic Calciorthids (18.43) to Typic Salorthids (391.32). This variation between soil type may be

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*McNeil, J.D. 1980. Electrical conductivity of soils and rocks. Geonics Ltd. Mississauga, Canada. Technical Note TN-5. 22 pp.

related to variations in moisture contents or the concentration of soluble salts in the soil profile. A more detailed investigation is necessary to establish these relationships.

Two transects with equally spaced (30.5 m) observation sites were established on Mormon Mesa. A 1707 meter transect (Transect A) provided 57 observation sites; and a 610 meter transect (transect B) provided 21 observation sites. On Mormon Mesa, electromagnetic conductivity averaged 7.8 mS/m with a range of 4 to 15 mS/m. Elevations varied from 643 to 664 meters.

On Mormon Mesa the correlation between elevation and soil electrical conductivity was r = 0.763 (Fig. 1). A cap of loamy sediments of variable thickness overlies a caliche layer on Mormon Mesa. As this cap appears to increase with elevation, variations in conductivity may be related to variations in the thickness of this cap and the depth to caliche. Further ground truth measurements are needed to confirm whether the EM meter can be used to map the depth to caliche on Mormon Mesa.

Two transects with equally spaced (15.2 m) observation sites were established on the intermediate or Grapevine site. A 320 meter transect (Transect A), which was orientated parallel with the slope, provided 22 observation sites; and a 168 meter transect (transect B), which was orientated perpendicular to the slope, provided 12 observation sites. Electromagnetic conductivity averaged 18.4 mS/m with a range of 11 to 90 mS/m. Elevations varied from 511 to 518 meters.

At the intermediate site, correlation between elevation and soil electrical conductivity was r = 0.071 (Fig. 2). The 90 mS/m measurement was obtained at the site of an earlier soil pit. It is believed that the electromagnetic conductivity of these soils increase with soil depth and anomalous measurement was an artifact produced by the covered the soil pit. Variations is the distribution and thickness of wind blown or washed sediments and carbonates may be responsible for the variation observed with the EM meter.

Three transects with equally spaced (15.2 m) observation sites were established across the flood plain of the Virgin River. Values for the measured electromagnetic conductivity were highest at his site and averaged 391.3 mS/m with a range of 36 to 920 mS/m. Elevations varied from 411 to 420 meters. The correlation between elevation and soil electrical conductivity was r = -0.455 (Fig. 3). The highest EM values were obtained on the terrace with relatively low values on the adjoining, more elevated (>414 m) backslope positions (see Fig. 3). Excluding the backslope areas, no significant correlation existed between elevation and soil electrical conductivity (r = 0.100). Inverse salt profiles (EM values decreasing with depth) were observed on the terrace. Inverse salt profiles have been related to seep or over wash conditions.

I feel more can and should be done as the results leave me uncomfortably "hanging". What do you think? Talk with you on my return in October. With kind regards.

Jim Doolittle

James A. Doolittle
Soil Specialist (GPR)

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ELECTROMAGNETIC INDUCTION AND GROUND-PENETRATING RADAR SURVEYS; MORMON MESA, NEVADA

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ELECTROMAGNETIC (EM) SURVEY

The EM-38 electromagnetic ground conductivity meter was developed specifically for measuring soil conductivity within the root zone (McNeill, 1986a). The meter has been used extensively to measure the apparent electrical conductivity of saline (Corwin and Rhoades, 1982 and 1984; De Jong, 1979; Kingston, 1985; Rhoades and Corwin, 1981; Rhoades and Halvorson, 1977; Slavich and Read, 1985; Williams, 1983; Williams and Baker, 1982; William and Hoey, 1987; and Wollenhaupt et al., 1986) and sodic (Ammons et al., 1989) soils. This technology has also been used to map bedrock surfaces (Zalasiewicz, 1985), thickness of clays (Palacky, 1987) or sand and gravel deposits (Rumbens, 1984), and for groundwater investigations (McNeill, 1988).

The operation of the EM-38 meter is described in detail by McNeill (1986b). Electromagnetic (EM) methods measure the electrical conductivity between the receiver and transmitter coils. For surveying, the EM-38 meter is placed on the ground surface or suspended at a specified distance. An oscillating dipolar magnetic field is produced by the transmitter coil. This primary magnetic field induces an electrical current in the ground which generates a secondary magnetic field in a manner that the amplitude of the induced current is proportional to the electrical conductivity of the scanned earthen materials. The magnitude of this current is measured at the receiver coil and is a function of the apparent electrical conductivity of the soil.

Electromagnetic methods measure the apparent electrical conductivity of earthen materials. Factors influencing the conductivity of earthen materials include (i) the volumetric water content, (ii) amount and type of salts in solution, (iii) the amount and type of clays in the soil matrix, and (iv) the soil temperature. The apparent conductivity (ECa) of the soil has been related to the paste extract conductivity (ECe) by the relationship ECa 5ECa (McNeill, 1986a). Table 1 (from McNeill, 1986a) illustrates this relationship. Measurements are expressed in millisiemens/meter (mS/m).

As discussed by Benson and others (1984), the absolute values are not necessarily diagnostic in themselves, but lateral and vertical variations in conductivity are significant. Interpretations of the EM data are based on the identification of spatial patterns in the data set.

Table 1

Soil Conductivity vs Salinity (from McNeill, 1986a)

Salinity	ECe(mS/cm)	ECa(mS/m)
Slight	0-4	0-80
Moderate	4-8	80-160
High	8-12	160-240
Extreme	>12	>240

An electrical conductivity survey, using electromagnetic induction (EM) methods, was carried out at three sites near Mesquite, Nevada. The purpose of this investigation was to map variations in apparent electrical conductivity with landscape position. It was anticipated that changes in electromagnetic conductivity could be related to differences in soil properties and could be used to map and to characterize soils.

A Geonic Limited EM-38 electromagnetic induction soil conductivity meter was made available for this study by the North Dakota Soil Conservation Committee. With the EM-38 meter placed on the surface and orientated in a vertical dipole position, measurements of apparent electrical conductivity were made to depths of about 1.5 meters.

Vertical EM conductivity readings were made along transects on Mormon Mesa (Fig. 1), at the Grapevine or the intermediate site along the northern flank of Mormon Mesa (Fig. 2), and near the Virgin River (Fig. 3).

Two transects with equally spaced (30.5 m) observation sites were established on Mormon Mesa. Elevations varied from 643 to 664 meters. A 1707 meter transect (Transect A) provided 57 observation sites; and a 610 meter transect (transect B) provided 21 observation sites. On Mormon Mesa, the apparent electrical conductivity averaged 7.8 mS/m with a range of 4 to 15 mS/m.

On Mormon Mesa the correlation between elevation and electrical conductivity was r = 0.763 (Fig. 4). A cap of loamy sediments of variable thickness overlies a caliche layer on Mormon Mesa. As this cap appears to increase with elevation, variations in conductivity may be related to variations in the thickness of this cap and the depth to caliche. Further ground truth measurements are needed to confirm whether the EM meter can be used to map the depth to caliche on Mormon Mesa.

Two transects with equally spaced (15.2 m) observation sites were established on the intermediate or Grapevine site. Elevations varied from 511 to 518 meters. A 320 meter transect (Transect A), which was orientated parallel with the slope, provided 22 observation sites; and a 168 meter transect (transect B), which was orientated perpendicular to the slope, provided 12 observation sites. The apparent electrical conductivity averaged 18.4 mS/m with a range of 11 to 90 mS/m.

At the intermediate site, correlation between elevation and conductivity was r = 0.071 (Fig. 5). In Figure 5, the abnormally high, 90 mS/m measurement was obtained at the site of an earlier soil pit. It is believed that the conductivity of these soils increase with soil depth and the anomalous measurement was an artifact produced by the filled soil pit. Variations is the distribution and thickness of wind blown or washed sediments and carbonates may be responsible for the observed variations in conductivity.

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The three sites were significantly different in terms of apparent electrical conductivity. ANOVA revealed a significant difference (.001 level) in conductivities among these sites. Generally, the apparent electrical conductivity decreased with elevation (r = -0.655). The averaged value for apparent electrical conductivity changed with dominant soil type from Typic Paleorthids (7.78) to Typic Calciorthids (18.43) to Typic Salorthids (391.32). This variation among soil types may be related to variations in moisture contents or concentration of soluble salts in the soil profile. A more detailed investigation is necessary to establish these relationships.

GROUND-PENETRATING RADAR (GPR) SURVEY

The GPR system used in this study was the SIR System-8 manufactured by Geophysical Survey System, Inc. Components used in this study included the model 4800 control unit, an ADTEK SR 8004H graphic recorder, an ADTEK DT 6000 tape recorder, a power distribution unit, and the 120 MHz antenna.

The GPR system is an impulse radar system which has been designed for shallow subsurface investigations. The operation of the GPR is described in detail by Olson and Doolittle (1985). Short-duration pulses of electromagnetic energy are radiated into the ground from the transmitting antenna. When a pulse contacts an interface separating layers of differing electromagnetic properties, a portion of the energy is reflected back to the receiving antenna. A continuous cross-sectional profile of shallow subsurface conditions can be displayed on the graphic recorder or recorded on magnetic tape for future playback or processing. A graphic recorder uses a variable gray scale to display data.

In recent years there has been a notable increase in the number and types of GPR applications in the field of soil science. Applications include: characterizing soil map unit composition (Johnson, et al., 1979; Doolittle, 1982 and 1987), determining water table depths in coarse-textured soils (Shih, et al., 1985), summarizing microvariability in the depths to soil horizons (Collins and Doolittle, 1987), characterizing soil properties (Doolittle, 1982), determining the depth to bedrock (Olson and Doolittle, 1985), assessing soil-landscape relationships (Puckett et al., 1986; and Rebertus et al., 1989), and improving soil-salinity management (Shih et al., 1985).

The GPR does not perform equally in all soils. The maximum probing depth of GPR is, to a large degree, determined by the conductivity of the soil. Soils having high conductivities rapidly dissipate the radar's energy and restrict the effective probing depth. Again, the principal factors influencing the conductivity of soils to electromagnetic radiation are: (i) degree of water saturation, (ii) amount and type of salts in solution, and (iii) the amount and type of clay.

The performance of the GPR at the various sites near Mesquite, Nevada, was generally poor. It is believed that the relatively high concentrations of soluble salts in the soil profiles restricted the profiling depth of the GPR. The profiling depth of the GPR decreased as the apparent electrical conductivity measured with the EM meter increased. This relationship is shown in Table 2.

TABLE 2

Comparison of
Electromagnetic measurements with GPR profiling depths at various sites near Mesquite, Nevada

Site	Dominant Soils	EM-V Average (mS/m)	GPR Profiling Depth (meters)
Mormon Mesa	Paleorthids	7.8	1.0 to 1.5
Grapevine	Calciorthids	16.2	0.5 to 1.0
Virgin River	Salorthids	391.3	> 0.5

GPR performed best in areas of Paleorthids on Mormon Mesa. Along the Mesa, the GPR provided continuous profiles of the subsurface to depths of about 1 meter. In areas where the caliche was at or very near to the surface, the radar profiled to depths of 1.5 to 2.0 meters. Images of the Bk and Bkm horizons were evident on the radar profiles. Variations in the expression and the continuity of these horizons were discernible on the radar profiles (see Fig 7).

Figures

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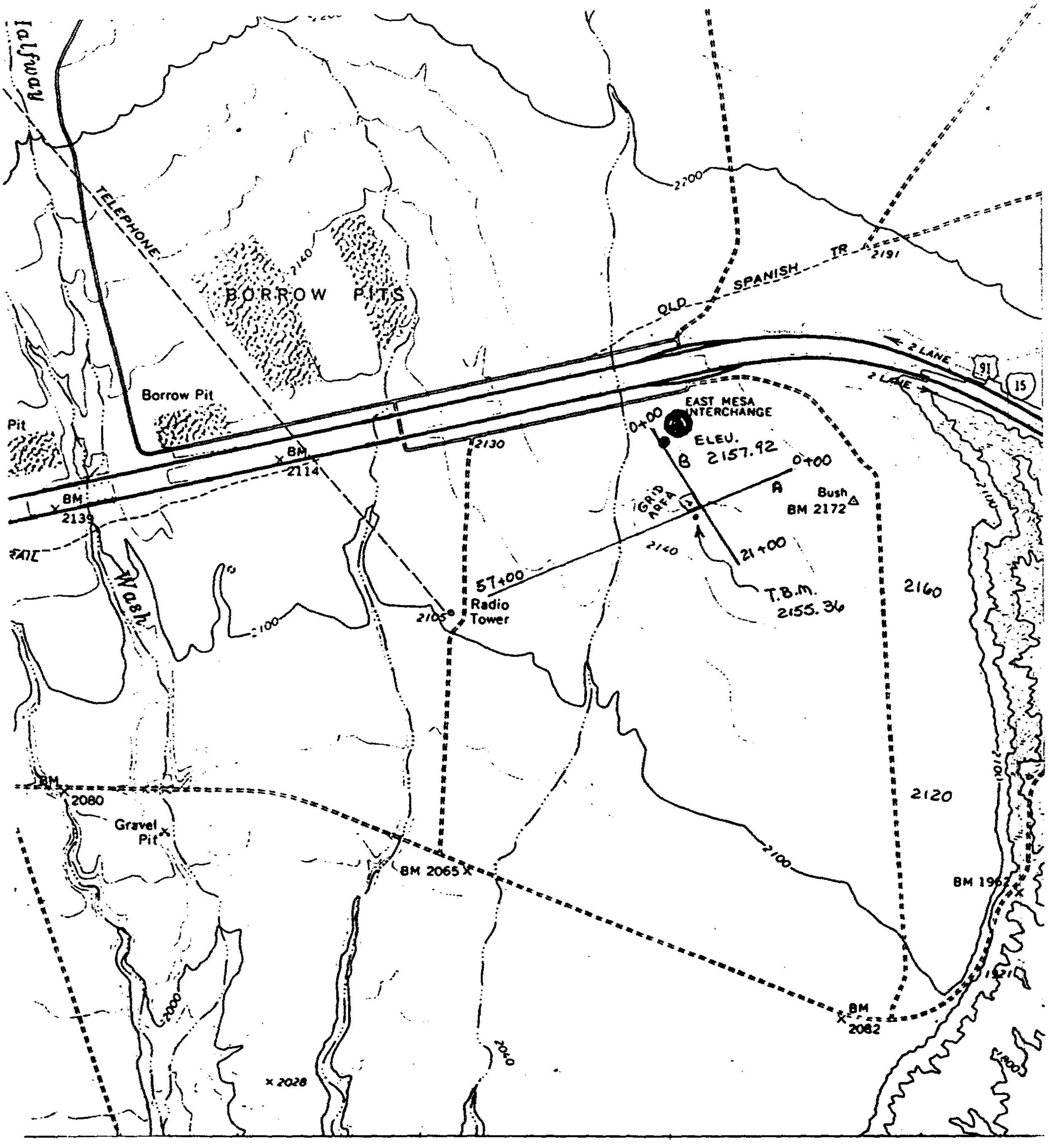
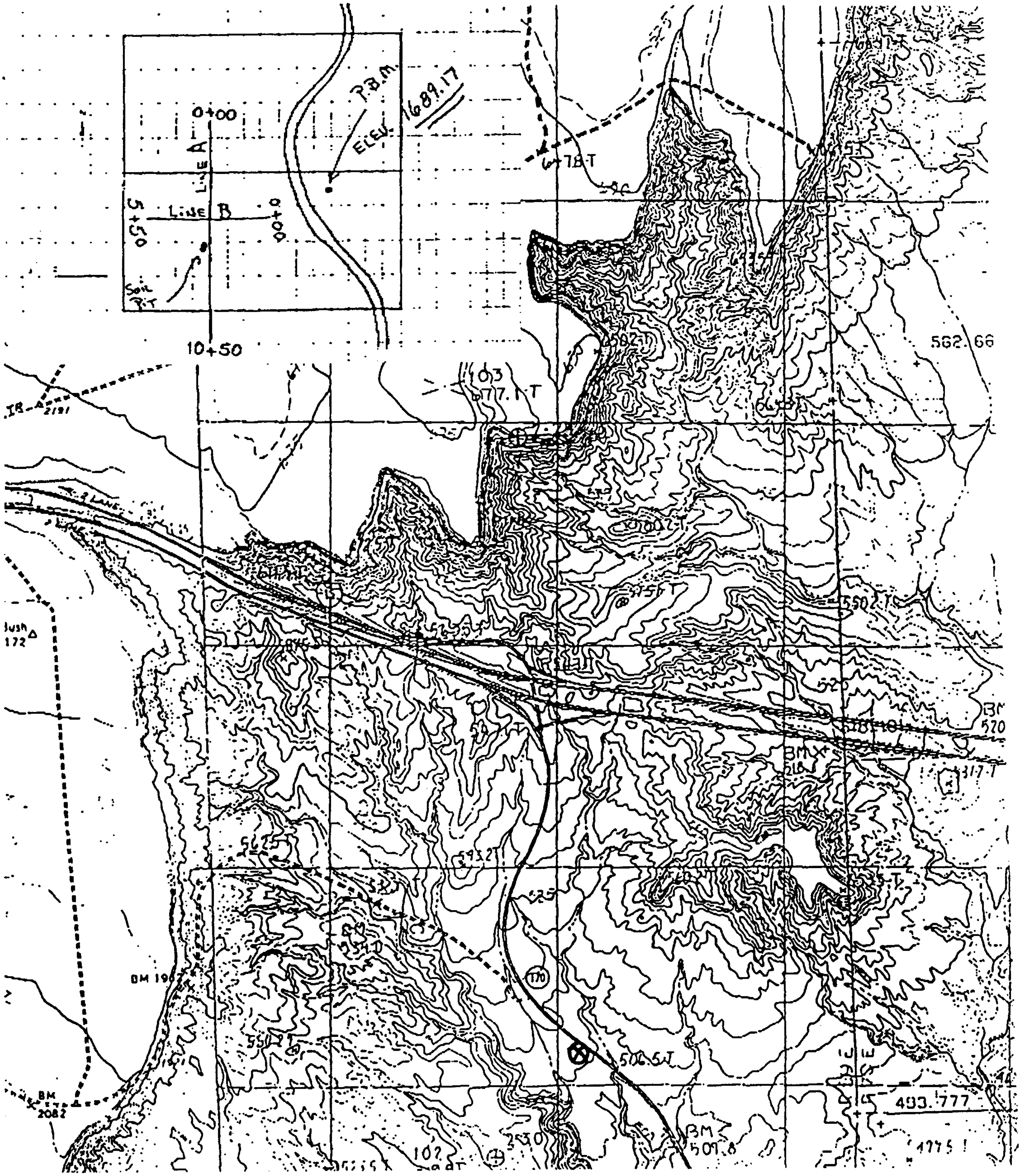


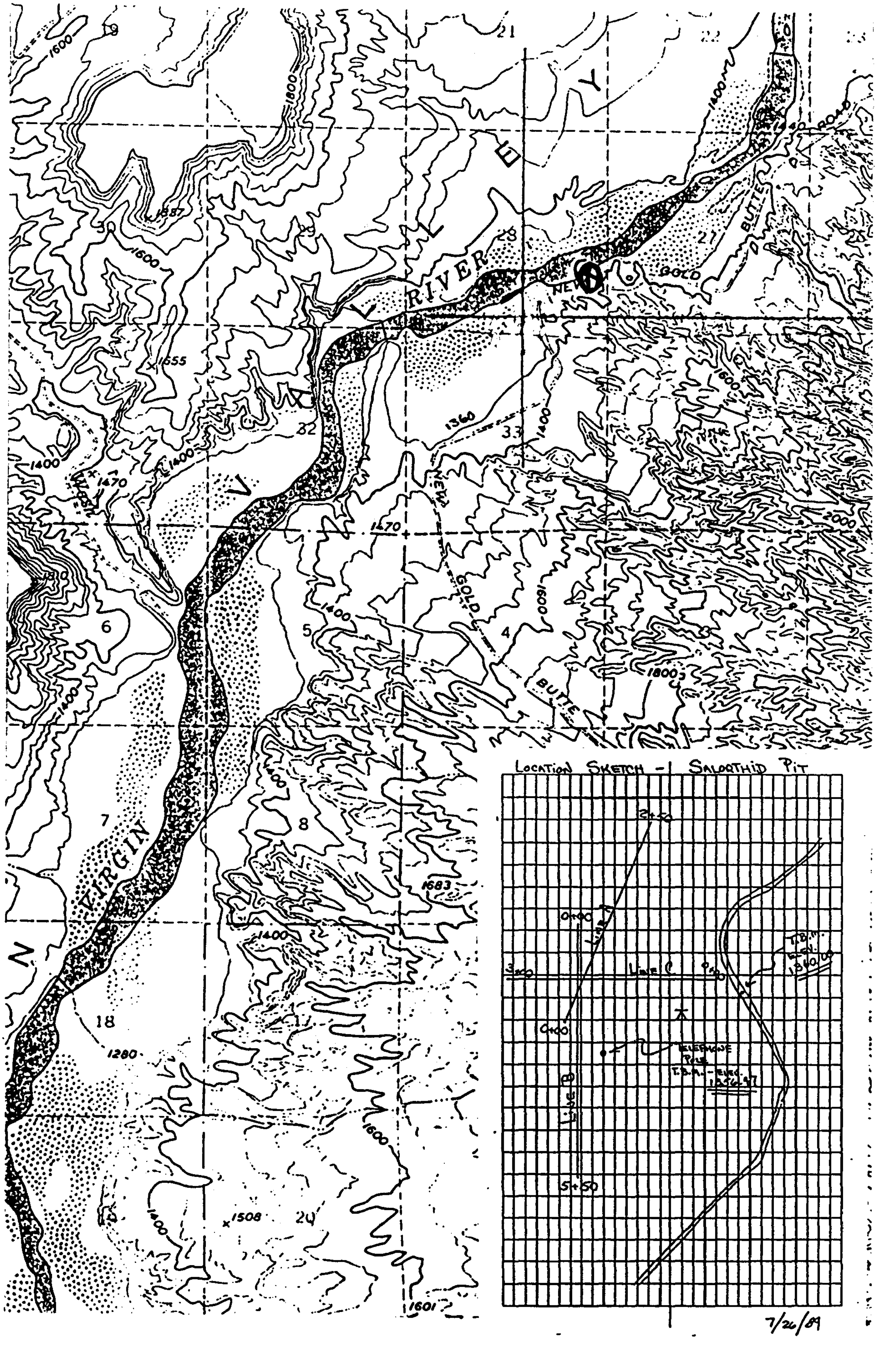
Halfway
TELEPHONE
BORROW PITS
2140
Borrow Pit
Pit
BM 2114
BM 2139
Wash
2100
Radio Tower
2105
2130
2200
OLD SPANISH TR
2191
2 LANE
91
15
EAST MESA INTERCHANGE
0+00
ELEV.
B 2157.92
0+00
A
GRID AREA
Bush
BM 2172
2140
21+00
57+00
T.B.M.
2155.36
2160
2120
2100
BM 2080
Gravel Pit
BM 2065
BM 2082
BM 1962
2000
2040
× 2028

Fig 1.



P.B.M.
ELEV.
689.17
0+00
LINE A
LINE B
5+50
0+00
Soil Pit
10+50
582.66
BM
520
170
506.5 T
BM
509.8
493.777

Fig 2



RIVER
VIRGIN
NEW GOLD BUTTE
GOLD
BUTTE
ROAD
LOCATION SKETCH - SALOATHID PIT
LINE A
LINE B
LINE C
2+50
0+00
3+00
0+00
5+50
TELEPHONE POLE
T.B.M. - ELEV. 1256.47
T.B.M. ELEV. 1360.09
7/26/89

Fig. 3.

MORMON MESA SITE

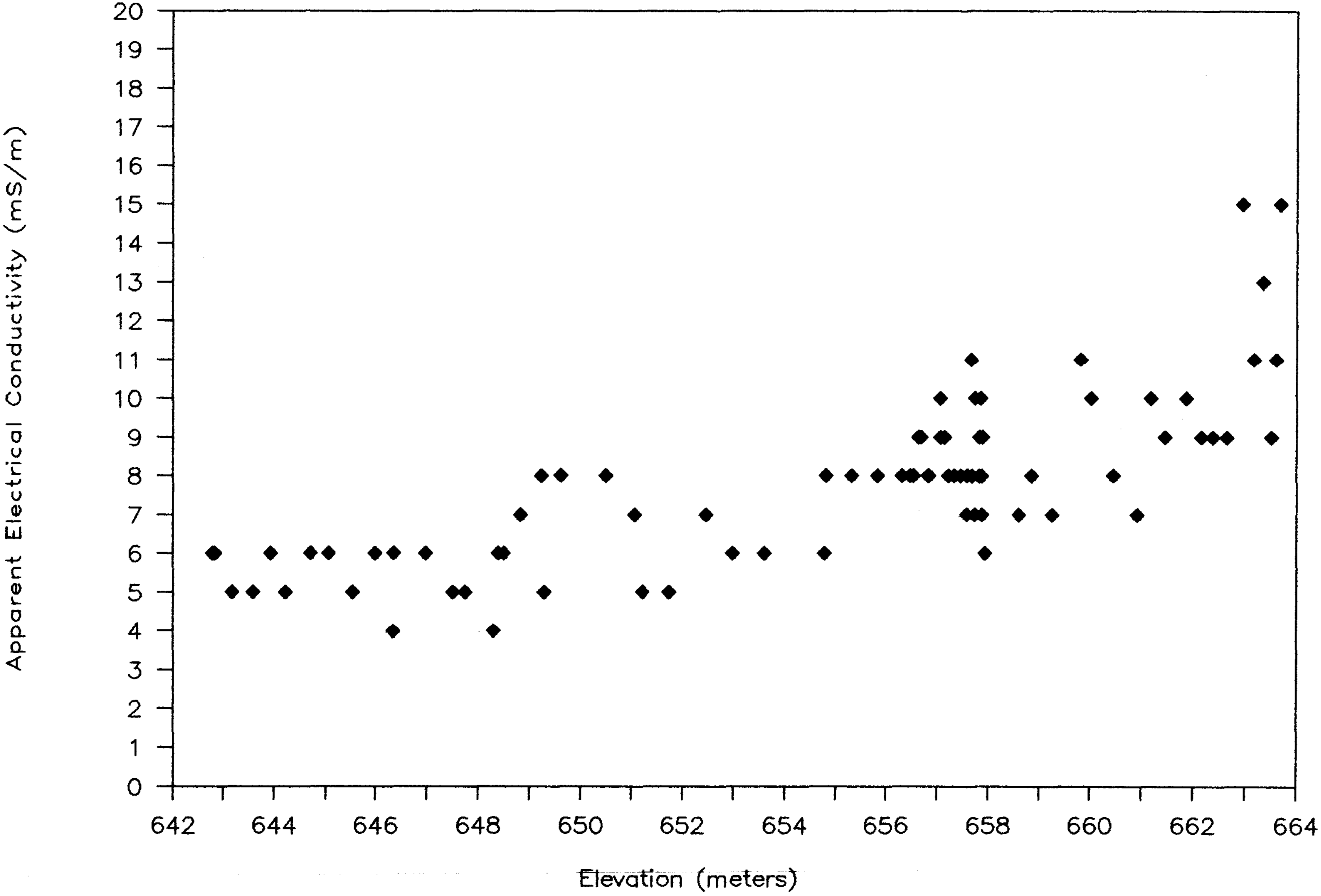


Fig. 4

GRAPEVINE SITE

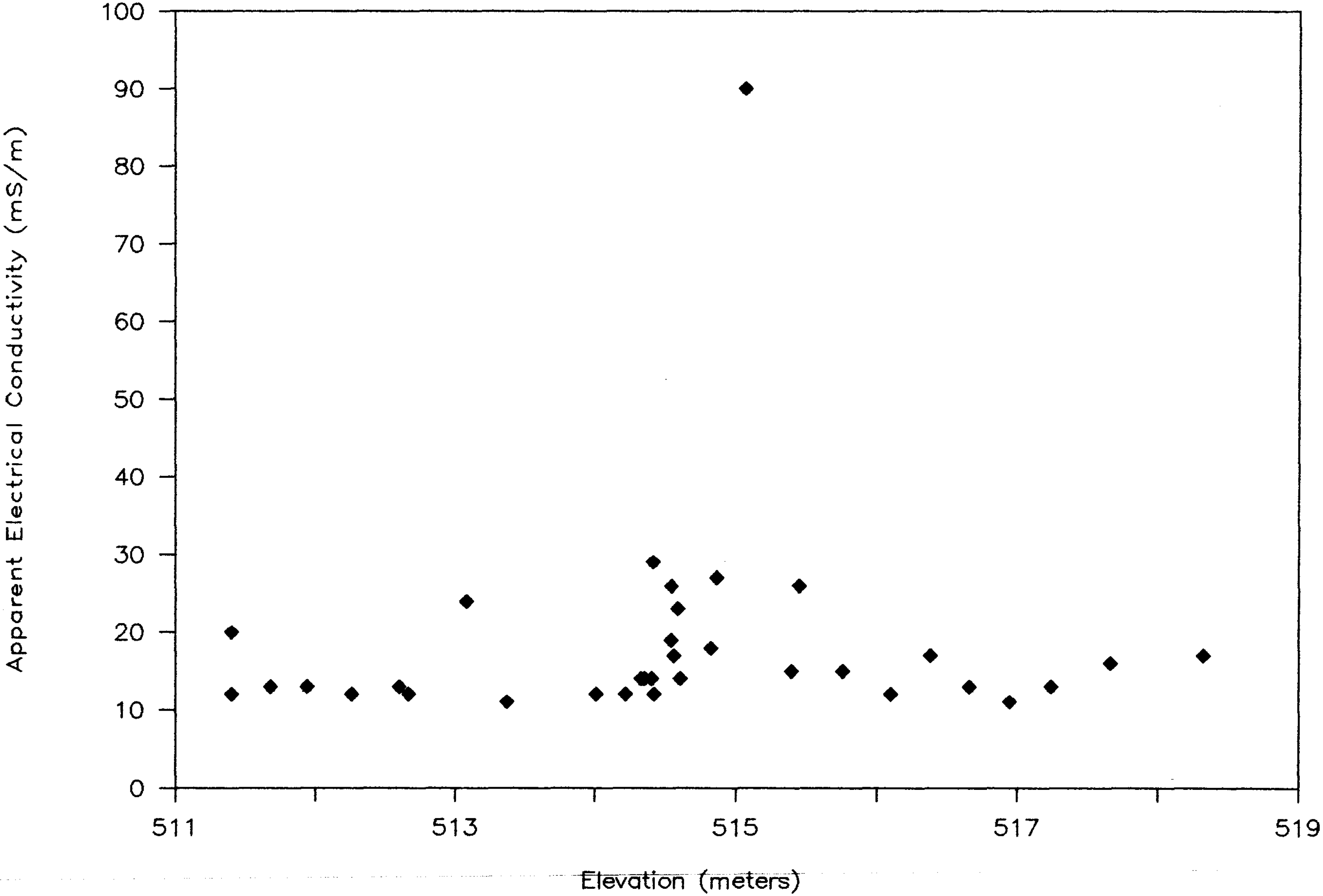
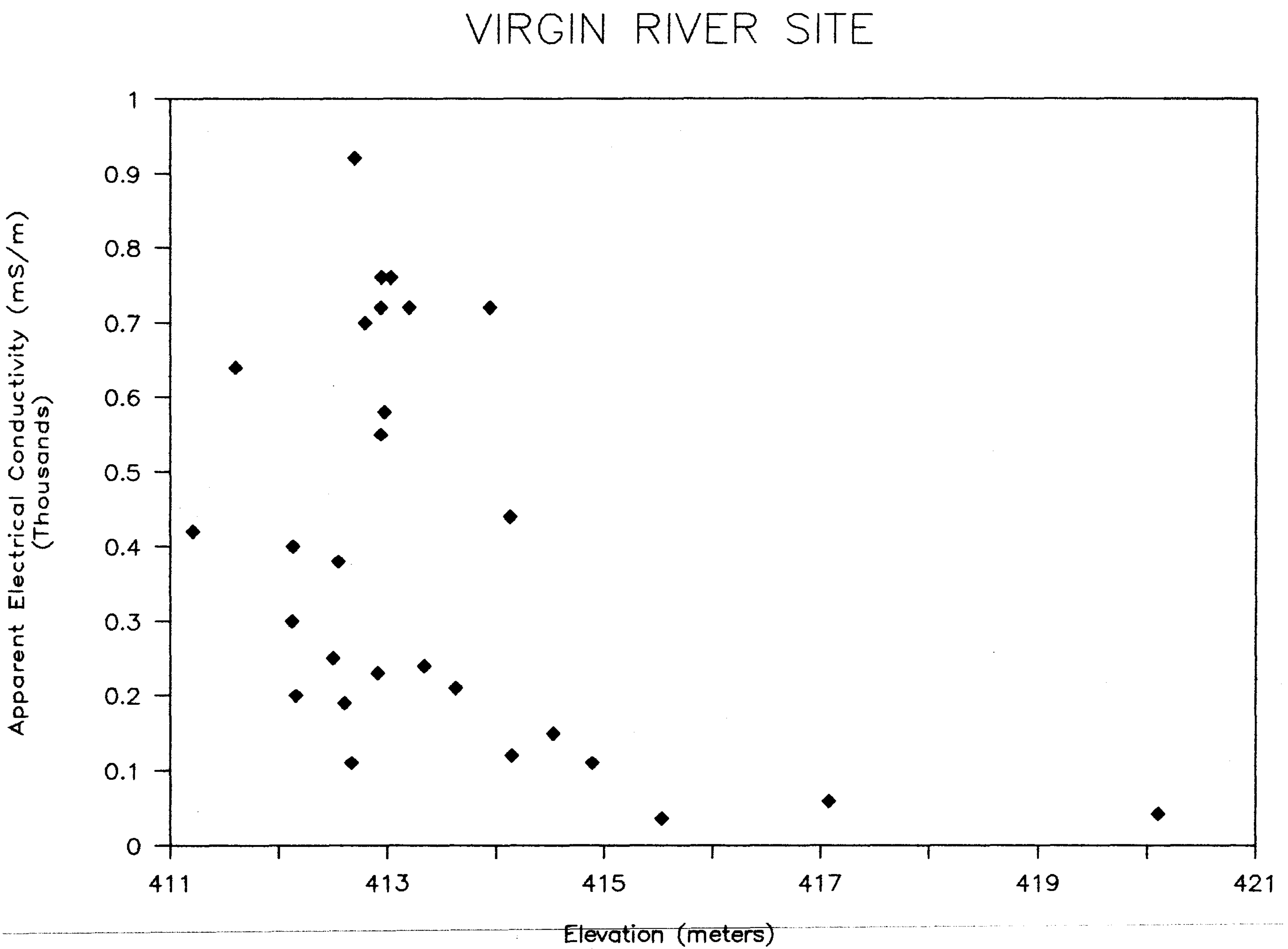


Fig. 5



VIRGIN RIVER SITE
Apparent Electrical Conductivity (mS/m)
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
411
413
415
417
419
421
Elevation (meters)

Fig. 6.

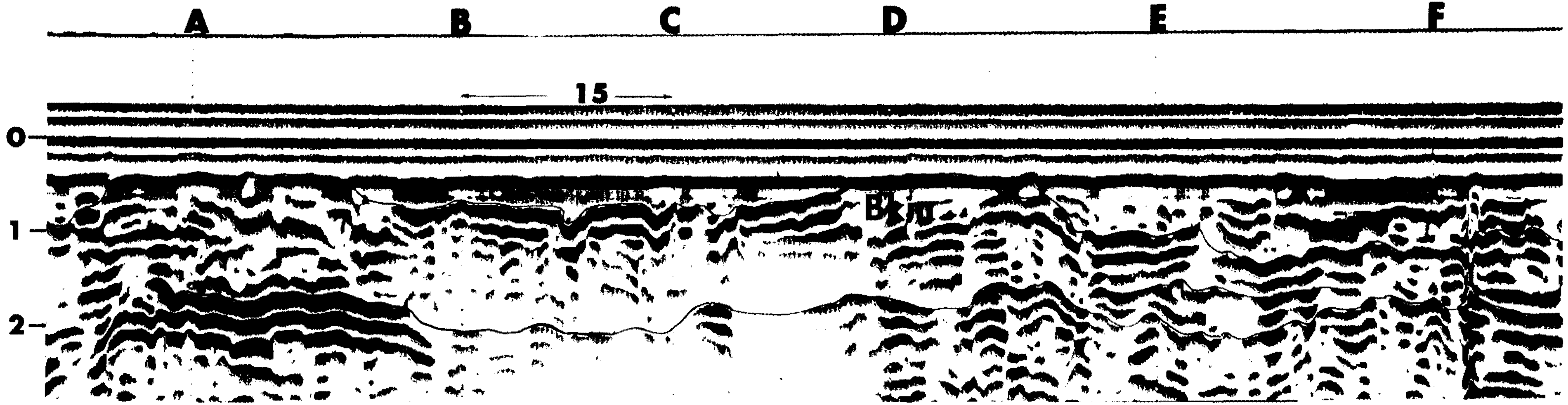


Fig. 7