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Recovery of soils and vegetation in World War II military base camps, Mojave Desert

by

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INTRODUCTION

The U.S. Army Desert Training Center (DTC) was established in April, 1942 by General George S. Patton, Jr. for the purpose of training tank forces in desert warfare techniques. The DTC encompassed 47,105 km^2 (17,500 mi^2) of arid lands in California, Nevada, and Arizona, including parts of the Mojave, Great Basin, and Sonoran Deserts (Fig. 1). Training operations were conducted from twelve main base camps, each occupied by as many as 15,000 soldiers at any given time. When the camps were abandoned in 1944 most physical structures such as maintenance sheds, water tanks, etc., were removed, but no apparent measures were taken to rehabilitate the land. Environmental changes caused by the military activities remain evident today at the sites of ten former camps (Fig. 2); two camp sites have been plowed for agricultural use.

Our study examines the degree to which soils, surface hydrologic characteristics, and vegetation have recovered by natural processes in the 40 years since the camps were abandoned. Disturbances ranging from vegetation clearing and soil trampling in tent areas to road grading and subsequent heavy vehicle usage were studied to assess the importance of disturbance thresholds in recovery. The remoteness of the camps from urban centers has kept post-abandonment human impacts to a minimum except on the most easily accessible roads.

The camps studied are on similar terrain, but have somewhat varying soil and vegetative characteristics. Variable response to the same types and intensities of use have important management implications that will be discussed in a future report.

Previous Work

Previous studies of soil and vegetation recovery of arid lands disturbed by military maneuvers are few in number (Wilshire and Nakata, 1976; Lathrop, 1980; Prose, 1985). Studies of recovery of arid lands in the southwestern U.S. from other similar disturbances are, however, relevant. These include studies of mining townsites abandoned as much as 70 years ago (Webb and Wilshire, 1980; Webb and others, in prep.), and studies of utility corridor disturbances (for example, Johnson and others, 1974; Vasek and others, 1975a, b; Brum and others, 1983; Kay and Graves, 1980a, b). These studies show that natural desert systems can remain significantly disrupted for long periods after even relatively minor levels of impact, and that reclamation of highly disturbed lands is difficult.

SETTING

The five base-camps are: 1) Camp Ibis, 2) 'old' Camp Clipper, 3) 'new' Camp Clipper, 4) Camp Iron Mountain, and 5) Camp Granite. They are all located in the eastern part of the Mojave Desert in California on lands managed by the U.S. Bureau of Land Management (BLM) (Fig. 3). The elevations of the camps range from 427 m at Camp Iron Mountain to 570 m at Camp Clipper. Average yearly rainfall in Needles, Ca., while quite variable, is 10.3 cm. Average January and July temperatures are 12.0 C and 35.2 C, respectively (weather data collected at Needles, Ca. airport from 1940 through 1980).

The camps were designed and constructed similarly, and their areas vary from approximately 2500 acres at Camp Iron Mountain to 7000 acres at Camp Granite. A grid pattern of 8-meter-wide roads was typically graded to a depth of 10-20 cm. In the more dissected parts of Camp Ibis, cut-and-fill methods of road construction were employed; some cuts are as deep as 2 meters. Tent and tank parking/service areas were cleared of vegetation by soldiers using hand tools under simulated battle conditions. Figure 4 is an aerial view of the two Clipper camps during the training period.

Creosote (Larrea tridentata) bush scrub is the typical plant community throughout the camps (community nomenclature of Munz, 1974; Thorne, 1976; Vasek and Barbour, 1977). The perennial shrub Ambrosia dumosa, a common associate in this community, occurs along with L. tridentata at all camp sites. Other principal perennials include Krameria parvifolia, Hymenoclea salsola, Encelia spp., and Opuntia spp., although there is local variation from camp to camp in the composition and abundance of species.

The camps are situated on the lower portion of gently sloping ($0-3^{o}$) bajadas, except for Camp Iron Mountain, which is located halfway between the adjacent mountain range and the bottom of the local basin. Ground surfaces chosen for study are incised by a network of closely-spaced shallow drainage channels from 25 cm to 5 meters wide and 3-20 cm deep, along which the highest concentration of perennial vegetation is found. Alluvial sediments are sandy gravels composed of granitic, volcanic, and various metamorphic rock clasts interbedded with coarse gravelly sands. The properties of the sediments and soils vary among the different camps, but studies at each camp were limited to similar surface/subsurface regimes.

A well-developed cryptogamic crust blankets 30-50% of the intershrub areas at Camps Iron Mountain and Granite, and scattered gravels 1-5 cm in diameter cover up to 20% of the surface at all camps. Undisturbed soils consist of a silty vesicular A horizon 1-3 cm thick underlain by a B horizon of alternating fine and coarse gravelly sand layers. The A horizon is dark brown and the B horizon grades from brown to red due to increasing oxidation with depth. A calcic K horizon of gravels and gravelly sands which have well-developed carbonate coatings and interstitial carbonate (stage II-III of Gile and others, 1966; and Bachman and Machette, 1977) occurs below the oxidized zone at a depth of 30-90 cm. All soils are Typic Calciorthids, gravelly sands, sands, or loamy sands, mixed, thermic, calcarious (except old Clipper, which has no carbonate). See Table 1 for site-specific soil data.

METHODS

Four types of areas that underwent different degrees of impact were identified and located from aerial photographs, military maps and records, and on-site ispection. From highest to lowest intensity of use, these study areas, or use-categories, are:

1) main roads- vegetation cleared and roadways graded to a depth of 5-20 cm. The roads were heavily used by all types of vehicles such as tanks, trucks, jeeps, etc. (Figs. 5,6).
2) vehicle parking lots- vegetation cleared with hand tools (Figs. 7,8).
3) tent roads- vegetation cleared with hand tools. "Alleyways" between troop tent rows were subjected to heavy foot traffic and also occasional jeep traffic (Figs. 9,10).
4) tent sites- vegetation cleared with hand tools. Floorless canvas tents, each housing 6 soldiers plus gear, were aligned back to back in single or double rows (Figs. 9,10).

Control plots (Fig. 11) were located as close as possible to disturbed areas to assure that soil and vegetation characteristics were constant between all study plots. Unfortunately, there are no completely undisturbed surfaces of requisite size within a few miles radius of all the camps because training activities were very intensive during the 2-year period of use. Our control plots all sustained some disturbance, but heavily-impacted areas were avoided. Some of the main roads are still used today by campers, hunters, and artifact seekers. We chose the most remote and least-accessable roads for study, but even these may have sustained some usage in the past 40 years. The tent sites, tent roads, and vehicle parking areas have undergone very little, if any, post-training vehicle impact, except at the two Clipper camps. A major tank training maneuver was held in the vicinity of these camps in 1964 (Operation Desert Strike), and scattered tank tracks left from this exercise are present.

Soil and Geomorphic Studies

Two trenches were excavated in all study plots to characterize subsurface soil profiles, and to document similarity of soil properties from plot to plot. Soil samples were taken in each use-category and the controls with a fixed-volume, piston-driven cylinder; surface stones and/or lichen crusts were removed before sampling. Ten samples were collected at 10 cm intervals to a depth of 30 cm, totaling 30 samples in each category. Each sample was oven-dried for 24 hours at 105°C and analyzed for bulk density and water content (% total weight). Random samples were analyzed for calcium carbonate content using a modified Chittick apparatus (Dreimanis, 1961), and for particle-size distribution using the hydrometer method (Day, 1965). Particle-size distribution curves (Figs. 37 through 41) depict results for the 0-30 cm soil depth range.

200 recording penetrometer measurements (Carter, 1967) were made to a maximum depth of 60 cm in all study plots. The instrument was fitted with a 30° steel cone tip. It is common practice when interpreting recording penetrometer results to analyze only mean penetrometer resistance values at selected depths. The percentage of measurements penetrating to selected depths is usually not considered because the penetrometer does have an adequate workable range for most soils. In highly compacted soils, frequency of penetration usually occurs to a lesser extent, and to shallower depths,

than in similar, uncompacted soils. Where penetration of compacted soils is achieved, it is not correct to assume that the resistance values attained represent values for the soil profile in other areas of the same study plot that could not be penetrated. Our bulk density results show that soils with relatively higher density (compaction) values in the 0-10 cm depth interval also have higher values from 10 to 30 cm depth in most cases. This suggests that penetrometer values would likewise be higher to these depths in compacted study plots if the penetrometer were able to penetrate to 30 cm on every attempt. For this reason, we give equal consideration to mean resistance values recorded at a given depth as well as to the percentage of measurements reaching that depth. We have created a rating system that ranks these factors and assigns a number, called a Metzger value, to each set of readings taken in a given study plot. See Figure 12 for a detailed description. Differences in penetrometer resistance and bulk density values between disturbed and respective control plots were analyzed statistically using a t-test.

Wash channel frequency was measured at Camps Ibis, Iron Mountain and Granite to assess changes in runoff patterns brought about by disturbance. Transects in all study plots were measured at high angles with respect to the dominant drainage direction. Relative depth and width of each channel intersected were recorded, and classified as major (>3m width), medium (15 cm-3m), or minor (<15 cm). The number of channels intersected in each transect is expressed as channel density according to the following formula: $\frac{1}{\text{c.d.}_1}$ x 100= channel density. $\text{c.d.}_1 = \frac{\text{number of channels}}{\text{number of paces in transect}}$

Vegetation Studies

Vegetation was surveyed in November, 1983 at camp Ibis and March-May, 1984 in the remaining four camps. The perennial vegetation at camp Ibis was sampled from 20 m^2 rectangular plots and at all other camps by 50-100 m long x 2 m wide belt transects (Brower and Zar, 1977; Muller-Dombois and Ellenberg, 1974). Belt transects were subdivided into 10 m intervals and one 1.0 m^2 and five 0.1 m^2 plots were nested within each interval for sampling respectively the herbaceous perennials, and the annuals and cryptogamic crust.

A stratified random sampling procedure was used to determine the location of the plots and belts in a particular study area (Greig-Smith, 1983). At old and new Clipper the total sample area was 400 m^2/category (n=20), at Granite and Iron Mt. 600 m^2/category (n=30) was sampled, and at Ibis the total area sampled was 240 m^2/category (n=12). For each study category, density (number of individuals per hectare) and cover (percent of ground surface covered by foliage) of the perennial shrub species were determined.

Herbaceous perennials were sampled using a .71 x 1.41 m rectangular plot (1.0 m^2) which was arbitrarily placed in the NW corner of each 10 m interval in the belt transect. The cryptogamic crust and annuals were inventoried with a 0.1 square-meter frame (.2 x .5 m) which was tossed every 2 m into the center of each 10 m interval of the transect. The density of herbaceous perennials and annuals was determined by species as the number of individuals per square-meter. Cover was estimated by dividing each plot into quarters and assigning each species to a coverage class (after Daubenmire, 1959), the midpoints of which were used to calculate average percent cover. Because it is impossible to count individual members of a cryptogamic crust in the field, only cover was estimated for each of two arbitrarily distinguished forms of crusts: flat ones and those with relief. A ratio reflecting the proportion of the two types of crust was calculated.

For each camp, the degree of quantitative recovery of the perennial shrubs in the four disturbed areas was estimated by determining the difference in total density and total cover between the control and each use-category. This difference is then represented as a percentage of the control and the less similar a disturbed area is to the control, the less recovered it is considered to be.

Mean shrub density and mean shrub cover were analyzed for significant differences between disturbed and undisturbed pairs by the t-test (Kershaw, 1973; Daniel, 1978). If the variation between samples exceeded differences expected from random variation alone, it was concluded that shrub density and/or cover in disturbed areas had not returned after 40 years to levels comparable with the control. A .05 or .01 significance level was used, implying, respectively, a 5% or 1% probability that the means were the same. Percent cover values were converted by angular transformation to normalize the distribution before being tested (Campbell, 1974). Bartlett's test (Snedecor and Cochran, 1967) was used to analyze the variances for homogeneity and where necessary, the t-test for unequal variances was employed.

Stable plant communities are typically composed of many long-lived individuals (Frank, 1968). For this reason, many investigators have used the percentage composition of long-lived perennials as a measure of stability in the creosote bush scrub community (Johnson and others, 1975; Vasek and others, 1975 a,b; Lathrop and Archbold, 1980 a,b). Lathrop and Archbold (1980a,b) further suggest using the percentage composition of common long-lived perennials as a qualitative measure to supplement quantitative comparisons. To elucidate changes in the quality of the vegetation between control and disturbed areas, all species were classified as either long-lived (LL), long-lived opportunistic (LL OPP), or short-lived (SL), according to the relative life span scheme of Johnson and others (1975) and Vasek (1983; oral communication, 1984). Total percent cover was calculated for each functional group. Relative cover- the total cover of a functional group expressed as a percentage of the total cover of all functional groups- was then determined. In each category of use, the proportion of cover contributed by a functional group was used as an index of dominance (Brower and Zar, 1975). Relative cover was also determined for the constituent species of each functional group.

RESULTS

The effects of the different types of military-related impacts on soils and vegetation are presented on a camp by camp basis, with data on soils and surface hydrology presented first.

Soils and Surface Hydrology

Camp Ibis (Fig. 13)

Camp Ibis is situated at the lowermost portion of a bajada, adjacent to Piute Wash. About 60% of lithic clasts in the alluvium are derived from Precambrian granitic rocks, and 40% from Tertiary volcanic rocks that are exposed in the Piute Range. Three geomorphic zones occur in the camp: the north end is situated on a surface with local remnants of varnished pavement of probable Pleistocene age that are dissected by deep, steep-banked washes; the central part of the camp is astride a younger, relatively flat surface that is incised by close-spaced, shallow washes; and a transitional zone of eroded terraces occurs at the south end of the camp and also is interspersed with the other two surfaces. We limited the comparative studies to the youngest surface in the central camp area because of sampling difficulties in the other two zones and because this surface is similar to geomorphic surfaces in the other four camps. Soils underlying this surface are classified as gravelly sands. Calcium carbonate content averages 2.5% in the 0-30 cm profile. The K horizon occurs in a depth range of 30-60 cm. Tent sites, parking areas, and main roads were bulldozed extensively in the south and north sections of the camp to reduce the local relief. It appears that the removal of desert pavement from previously unvegetated terrace surfaces may be promoting the colonization of these areas by plant species from the surrounding vegetation (Fig. 14). Further research is being carried out in a variety of disturbed pavement settings throughout the Mojave Desert to determine how commonly vegetation takes advantage of a broken pavement surface.

All disturbed areas show significant increases ($p=.01$) in penetrometer resistance to a depth of 20 cm, compared to the control (Fig. 15). In order of overall increasing resistance for each study plot, tent sites show the least, followed by tent roads, parking areas and main roads. This is the same order as increasing intensity of use of the disturbed areas. Percentage of measurements penetrating to corresponding depths is much lower for disturbed areas versus the control, especially in the tent roads, parking lots, and main roads. No penetration was possible below 10 cm in these use-categories because of extreme soil compaction. Metzger values (Fig. 16) differ between disturbed areas and the control by the following percentages: tent site, -37%; tent road, -80%; parking lot, -83%; main road, -87%. Metzger values are not significantly different between tent roads, parking lots, and main roads.

Increases in bulk density were recorded in the 0-30 cm depth range in all disturbed areas compared to the control (Table 2). Compared to an average density of 1.66 g/cm^3 in the control, percent increases in disturbed areas are: tent site, 2.4%; tent road, 6.0%; parking lot, 9.0%; main road, 10.8%. As with penetrometer results, bulk density values increase with increasing use-intensity.

Moisture content increases with depth in all use-categories at Camp Ibis (Table 3). The disturbed areas have slightly higher moisture contents at all depth intervals than the control, except the 20-30 cm depth interval in the tent site. There is a general increase in water content as use-intensity increases, though the tent road and parking lot have similar water contents at all depths.

Carbonate levels are higher in the parking lot and main roads than the control at corresponding depths (Table 4). However, 5 to 15 cm of soil was removed or has eroded away in these disturbed areas so that a truer comparison is made by matching the 10-20 cm/20-30 cm intervals in the control to the 0-10 cm/10-20 cm intervals in the parking lot and main roads. In this comparison, carbonate levels are still higher in the disturbed areas. Also, $CaCO_3$ levels are much more variable in the disturbed areas. The tent site has either comparable or lower $CaCO_3$ levels than the control.

Wash channel frequency averages 8.6 through the control plot, then increases to 14.1 (63% increase over control) as the drainage system passes through the parking lot (Fig. 17). Where a main road is intersected at a high angle by the drainage, most of the channels have broken through or spill over the upstream road berm and enter the road. The downstream berm prevents about 50% of these channels from continuing downslope and concentrates them into a few deeply-eroded gullies along the berm. Beyond the berm and into the tent/tent road area, the channels fan out and reestablish the same density as found in the parking lot.

The main roads in the north portion of Camp Ibis were constructed by cutting into the terraces to a maximum depth of 1.5 meters and filling in adjacent wash channels, creating a dam on the upstream side of the roadfills. Deposits of silty material have been accumulating behind the unbreached road-dams since construction and provide a record of runoff-producing rain events. Each runoff event is recorded by a pair of thin beds in which the lower coarse one grades abruptly upward to finer-grained sediment. A count of pairs indicates that at least 20 to 23 major runoff events have taken place at Camp Ibis since the Army closed the camp 40 years ago.

Camp Clipper

The two Clipper camps are situated close to one another, a long distance from the source areas of the alluvial substrate. Source materials are Mesozoic and Precambrian igneous and metamorphic rocks, arkosic rocks, and Tertiary volcanics exposed in the Providence and Woods Ranges. The soils are finer grained than those at the other camps and quite deep; the K horizon occurs at depths greater than 90 cm in most places. Carbonate content is very low to depths of 30 cm at new Clipper (0.1%), and undetectable at old Clipper. The 'old' camp was abandoned shortly after construction, probably because it was located in the path of several major wash channels that carry large volumes of runoff during heavy rainfall events. The 'new' camp was relocated higher up the slope on a more stable surface.

Old Camp Clipper (Fig. 18)

Penetrometer measurements (Fig. 19) indicate that significant increases in resistance occur only to a depth of 5 cm in disturbed areas compared to the control. The percentage of penetrations at corresponding depths, however, is much lower in all disturbed areas. Metzger values (Fig. 20) decrease gradually as use-intensity increases, but there is a large difference between the values for the parking lot and the main road. This may be due in part to continued use of the camp roads by vehicles enroute to maneuver areas after this temporary camp was shut down. Vehicles maneuvering during Operation Desert Strike in 1964 made use of these camp roads as well. Compared to the control, Metzger values for disturbed areas differ by the following amounts: tent sites, -14%; tent roads, -34%; parking lots, -30%; main roads, -82%.

All disturbed areas show increases in bulk density over an average control value of 1.55 g/cm^3 at each of the three soil depth intervals, and values increase as use-intensity increases (Table 5). The values for the tent sites are only slightly higher by 1.3% than the control. Tent roads are next higher by 3.9%, followed by parking lots, 5.2%, and main roads, 11.0%. The large increase in compaction between the parking lot and the main road, as shown by penetrometer values, is evident in density values as well.

Water content increases with depth in all categories of use (Table 6). Disturbed areas have slightly higher H20 contents than the control at all three depth intervals, but there is no correlation between increases in H20 content and use-intensity.

No carbonate was present to 30 cm in the control plot at this camp, nor was any $CaCO_3$ detected to 30 cm in the main roads (Table 7). A slight amount was found in the parking lot at the 10-20 cm and 20-30 cm depth intervals. The value for both intervals is 0.1%, with 0.2%-0.4% detected in 2/3 of the samples tested.

New Camp Clipper (Fig. 21)

All disturbed areas have much higher resistance values to 10 cm depth than the control (Fig. 22). The percentage of measurements reaching any particular depth is much lower than that for corresponding depths in the control, although penetration to 30 cm was attained in all the disturbed plots except the main road. Only two penetrations (to 5 cm) out of 200 were possible in the main road due to extreme compaction. Metzger values (Fig. 23) decrease as use-intensity increases. Compared to the control, Metzger values for disturbed areas differ by the following amounts: tent sites, -34%; tent roads, -60%; parking lot, -62%; main roads, -83%.

The disturbed areas all show increases in bulk density over control values to 30 cm depth, with a few exceptions in the 20-30 cm interval (Table 8). Density does not increase with use-intensity at this camp, nor do density value increases in disturbed areas, compared to the control, correlate with penetrometer resistance increases. In order of increasing density, disturbed areas have greater values than the control by the following percentages: parking lot, 0%; tent site, 1.9%; tent road, 5.1%; main road, 14.6%. The main road shows a large increase in density over the tent road.

Water content increases with depth in most categories, with exceptions in the tent road and main road (Table 9). All disturbed areas have higher H20 contents than the control in the 0-10 cm depth interval. In the 10-30 cm depth range, moisture content is higher in the tent site and parking lot, and lower in the tent roads and main roads in comparison to the control.

No carbonate was present in the 0-20 cm depth range in the control soils; 0.3% was detected in the 20-30 cm interval (Table 10). On the other hand, the tent site and parking lot contained 0.8% and 0.6%, respectively, in the 0-10 cm depth interval, 0.2% and 0.9% in the 10-20 cm interval, and 0.2% and 0.5% from 20-30 cm.

Camp Iron Mountain (Fig. 24)

This camp is located midway between the predominantly granitic (at the southern end) Iron Mountains Range and the lower end of the bajada. 30% to 50% of most of the undisturbed surface between wash channels is covered with an intermediate to well-developed black cryptogamic crust. Soils below the vesicular A horizon and above the K horizon are distinctly bedded medium to fine gravelly sand and the coarse particles have a high degree of angularity.

The tent roads and the parking lot at this camp were so compacted that only three penetrations (in the tent road, to 5 cm) were made in 400 attempts (Fig. 25). Readings are also significantly higher in the tent sites to a depth of 10 cm, compared to the control. Overall, the percentage of readings at any specific depth is much lower in all disturbed areas than at corresponding depths in the control. Metzger values (Fig. 26) differ from the control for disturbed areas by the following amounts: tent sites, -46%; tent road, -89%; parking lot, no penetrations; main road, -79%.

The soils in the control at this camp have the highest bulk density of all 5 camps studied; the average value for the 0-30 cm depth range is 1.70 g/cm^3 (Table 11). There are large density increases in all disturbed areas compared to the control in the 0-10 and 10-20 cm depth intervals. This trend does not extend to the 20-30 cm depth, except in the main road. Density values generally increase as use-intensity increases. Compared to the control, density values for the disturbed areas are higher in the 0-30 cm depth range by the following percentages: tent sites, 2.9%; tent road, 7.1%; parking lot, 6.5%; main road, 10%.

The control soils had an average H_2O content of 0.5% in the 0-30 cm depth range. Water content in all areas studied increases with depth (Table 12). The only significant deviation of water content values from the control soils in the disturbed areas occurs in the main road at the 10-20 cm and 20-30 cm depth intervals, and the tent road at the 20-30 cm interval where the water content is higher.

Carbonate content of these soils in the 0-30 cm depth range averages 0.4% to 0.6%. Average values for the control, tent site, and parking lot are not significantly different at all three soil depth intervals (Table 13).

Wash channel frequency averages 11.1 in the control plot, with 43% of the drainages classified as minor, 35% medium, and 22% as major (Fig. 27). As the drainage system enters a main road, the density decreases by 44% to 6.2. The downstream road berm diverts 2/3 of these channels. Channel frequency approximates the control value through the tent site, although the size characteristics of the channels are altered. One cause of this is the presence of a substantial network of stones outlining former sidewalks, tent rows, and even individual shrubs. The drainage pattern in the parking lot is altered drastically from the control plot. Channel frequency is 5.0 (55% less than the control value) in the upper portion of the parking lot, with an even distribution of channel sizes. Farther downslope, channel frequency increases to 6.5, thus giving an average frequency value for the parking lot of 5.6.

Camp Granite (Fig. 28)

This camp is located within one mile of Camp Iron Mountain. It is situated on the piedmont of the Granite Mountains. Source materials of the alluvium are predominantly Mesozoic granitic rocks with a small amount of altered mafic igneous rocks. A well-developed cryptogamic crust mantles the undisturbed soils at this camp. The soils are classified texturally as sands, but they contain the widest distribution of particle sizes of all five camps (Fig. 40). Material above the K horizon, which occurs at 40-50 cm depth, is distinctly bedded angular coarse and fine sand.

Penetrometer readings indicate that these granitic soils are the least cohesive of all soils studied at the five camps (Fig. 29). Readings could not be made in the tent roads as they are aligned parallel to the slope and have been converted into drainage channels. In the other disturbed areas, readings are significantly higher, and the number of measurements recorded at each depth is much lower compared to control results. Metzger values (Fig. 30) show that the soils in the disturbed areas at this camp have undergone the highest degree of compaction of all 5 camps studied. Compared to the control, Metzger values differ in the disturbed areas by the following percentages: tent sites, -49%; parking lot, -94%; main road, -78%.

Bulk density values indicate that soil compaction is significant at all measured depth intervals in the disturbed areas (Table 14). In the 0-30 cm depth range, values are higher than the control in the disturbed plots by the following amounts: tent site, 6.2%; parking lot, 14.4%; main road, 13.1%. Bulk density results agree with penetrometer readings in that the disturbed areas at this camp have been compacted to a greater degree than the soils at the other camps.

Moisture content of these soils was very low, as at Camp Iron Mountain, at the time of measurement (Table 15). Values range from 0.4% to 0.7% in both disturbed and undisturbed areas, and no significant differences are apparent among all categories at this camp.

Carbonate content was only measured in the control plot. The average value for the 0-30 cm depth is 0.7% (Table 16).

Wash channel frequency averages 8.8 in the control areas, with 50% of the drainages classed as major, 33% medium, and 17% minor (Fig. 31). A main road reduces channel frequency to 3.3 downslope from the control, and frequency is reduced to 1.7 along the downslope road berm. The tent sites have approximately the same average frequencies (9.4) as the control, and channel widths are likewise similar.

Vegetation results

The quantity (i.e., total density and total cover) and quality (i.e., dominant functional group as determined by relative cover) of the perennial shrubs in the control areas are compared with the same parameters in the disturbed areas. In addition, herbaceous perennials and annuals were sampled at all camps except Ibis, and the well developed cryptogamic crust present only at Camps Granite and Iron Mountain was also sampled. The herbs and annuals were generally present in very small quantities, so both density and cover values are pooled for these two groups of plants.

Camp Ibis

The diversity (11 species) and abundance of perennial shrubs in the control at camp Ibis are higher than in controls elsewhere. In addition to the common species Larrea tridentata and Ambrosia dumosa, other long-lived species include: Krameria parvifolia, Opuntia ramosissima, and Yucca schidigera. The short-lived species of the control include Dyssodia porophylloides, Encelia frutescens, Hymenoclea salsola, Porophyllum gracile, and Stephanomeria pauciflora (Tables 17,18). The total amount of cover provided by L. tridentata is 7.4% which is intermediate when compared with controls of other camps.

In comparison with the control, total shrub density and total cover are reduced in all categories of disturbance with the exception of density in the parking lot. The total density figures differ between the disturbed areas and the control by the following percentages: parking lot, +1.6%; tent sites, -21.0%; tent roads, -34.0%; main roads, -66.9%. Following in the same sequence as density, disturbed areas show reductions in total shrub cover of 26.6%, 33.9%, 47.4%, and 68.4% (Table 19). The reduction in density and in cover is significant in tent roads (p=.05 for density; p=.01 for cover) and main roads (p= .01), whereas the tent sites and parking lot are not significantly different from the control in either of these parameters (Fig. 32).

Along with fewer shrubs, qualitative alterations of the vegetative pattern exist. In each of the disturbed areas there is a shift in dominance away from the long-lived functional group towards the long-lived opportunistic functional group. The proportion of total cover (i.e., relative cover) contributed by the long-lived functional group decreases from the control by the following percentages: tent sites, 73.4%; tent roads, 100%; parking lot, 90,1%; main roads, 87.0%. On the other hand, relative cover of the sole long-lived opportunistic species, A. dumosa, increases by the following percentages: 74.5%; 66.7%; 69.4%; 39.9%. Relative cover of short-lived shrub species, especially E. frutescens and H. salsola, also increases in all disturbed areas (Table 18, Fig. 33).

Camp Clipper

The vegetative assemblage at the adjacent old and new Clipper camps consists of two shrub species: L. tridentata and A. dumosa, with Opuntia echinocarpa also present in low numbers in the control at new Clipper. The controls of these two camps are similar to one another and intermediate relative to controls of other camps with regard to total density and total cover of the perennial shrubs (Tables 17,18). L. tridentata provides approximately 11.5% of the total cover in these controls which is the highest percentage of all controls.

Old Camp Clipper

Total density of the perennial shrubs in tent sites and tent roads at old Clipper is greater than in the control by 13.4% and 3.1% respectively while density decreases in the parking lot by 42.3% and in the main roads by 49.5%. Total shrub cover progressively decreases in the categories of disturbance when compared to the control by the following percentages: parking lot, 30.5%; tent roads, 35.7%; tent sites, 50.0%; main roads, 60.4% (Table 19). The decrease in cover is significant in the tent sites (p=.05) and the main roads (p=.01) as is the reduction of density in the main roads (p=.05) (Fig. 32).

Although the total amount of shrub cover is reduced as a result of disturbance, L. tridentata is the dominant cover species in the tent roads and parking lot, as it is in the control. The long-lived opportunistic species A. dumosa, however, is dominant in the tent sites and main roads. Relative cover values of the long-lived species decreases from the control in disturbed areas as follows: parking lot, 5.7%; tent roads, 24.8%; tent sites, 51.1%; main roads, 65.2%. The long-lived opportunistic species conversely increases in relative cover (Table 18, Fig. 33).

Total density and cover of herbs and annuals in tent sites and tent roads is nearly the same as in the control; density ranges from 11.3 to 12.2 m^2 and cover ranges from 3.9 to 4.3 percent of the total area sampled in these three categories. The parking lot and main roads are the least similar to the control. Both density and cover of the microflora in the parking lot are nearly twice the values in the control whereas they are reduced by 90% in the main roads (Table 20).

In the control, the annual Plantago insularis is a major species in terms of density while the herbaceous perennial Hilaria rigida, which is present only in the control, and the annual grass Schismus arabicus are the prominent cover species. In tent sites and tent roads, virtually all of the density and cover is provided by S. arabicus. The increase over the control in cover and density in the parking lot is due primarily to a three-fold increase in the abundance of this introduced grass. P. insularis is also prominent in the parking lot and contributes slightly more to cover than in the control even though its abundance is somewhat less. Other species present in lesser numbers in some of the disturbed categories are the annual Cryptantha nevadensis and the herbaceous perennial Baileya multiradiata.

New Camp Clipper

When compared to the control, total density and total cover of perennial shrubs at new Clipper are decreased in all areas of disturbance. Percentage reductions in density are as follows: tent sites, 13.2%; tent roads, 50.6%; parking lot, 60.2%; main roads, 61.4%. The proportion of shrubby ground cover decreases in disturbed areas by the following percentages: tent sites, 24.2%; tent roads, 46.2%; parking lot, 62.1%; main roads, 57.6% (Table 19). The decrease in total cover and density is significant at the .01 level of probability in the parking lot and main roads, and at the .01 level for cover and .05 level for density in the tent roads. The tent sites are the only category of disturbance not significantly different from the control with respect to density and cover (Fig. 32).

L. tridentata, although its total cover is less than in the control, is the dominant species in all disturbed areas except the main roads. This relationship is different from that in all other camps except the neighboring old Clipper where L. tridentata is likewise the dominant shrub in a couple of the disturbance categories. Compared to the control, the decreases in the amount of relative cover provided by the long-lived functional group are: parking lot, 29.9%; tent roads, 32.6%; tent sites, 37.5%; main roads, 72.9%. A. dumosa (long-lived opportunistic) increases in relative cover 3 to 5 times over the control in disturbed areas and is the dominant species in the main roads (Table 18, Fig. 33).

Both total density and cover values of herbs and annuals in all disturbed areas at new Clipper are far less than control values. Reductions in density range from 67% to 100% and reductions in cover range from 53% to 100%, with the main roads showing the least amount of reduction in these two parameters; the parking lot does not support any of these plants (Table 20).

P. insularis is the most abundant species in the control with only a trace (0.1%) amount of C. nevadensis also present. These two annuals occur in small quantities in tent sites and main roads as well as C. nevadensis in the tent roads only. The herbaceous perennials Allionia incarnata and Dalea mollis are also found in the tent sites in minute quantities as well as a trace amount of D. mollis in the main roads.

Camp Iron Mountain

Seven perennial shrub species were sampled at the Iron Mountain camp. In addition to L. tridentata and A. dumosa, the long-lived species of the control include Encelia farinosa and Lepidium fremontii. The short-lived shrub species include Bebbia juncea, H. salsola, and S. pauciflora. The vegetation of the control is widely spaced with total density and total cover figures the lowest of all camps (Tables 17,18). The total L. tridentata cover in the control (5.5%) is less than in controls of all other camps except Granite. A cryptogamic crust covers 31% of the intershrub ground surface.

Compared with the control, total shrub density values for some disturbed areas at this camp show the largest increases and total cover values the largest decreases of any camp. Density values for disturbed areas differ from the control by the following amounts: tent roads, -10.5%; main roads, -64.2%; parking lot, +385.4%; tent sites, +435.3%. Compared to the control shrub cover of 6.7%, percent differences in disturbed areas are: tent sites, +1.5%; parking lot, +40.3%; tent roads, -83.6%; main roads, -88.0% (Table 19). The differences in density are significant (p=.01) in the tent sites, parking lot, and main roads. In the tent sites and parking lot, the difference is due to an increase in shrub density whereas the main roads exhibit a significant decrease in shrub density. Cover figures are significantly (p=.01) reduced from the control in the tent roads and main roads and, as with density, significantly (p=.05) increased in the parking lot (Fig. 32).

Changes in species proportions have also occured as a result of disturbance. Relative shrub cover of the long-lived species L. tridentata is reduced from the control while relative cover of the long-lived opportunistic species A. dumosa and the short-lived species H. salsola is increased in disturbed areas (Table 18, Fig. 33). Reductions in relative cover of the long-lived functional group range from 99.0% in tent roads, to 85.8% in the parking lot, 56.1% in tent sites and 19.0% in main roads. As in the control, the long-lived functional group is the dominant component of shrub cover in the main roads, but, unlike the control, the long-lived species is E. farinosa not L. tridentata. Relative cover of the long-lived opportunistic group increases 4 to 5 times over the control in tent sites and tent roads, and A. dumosa is the dominant species in these two categories. The short-lived functional group increases in relative cover in all areas of disturbance except for the main roads. In the parking lot, this group, dominanted by H. salsola, provides the major proportion of perennial shrub cover.

Total density and cover of herbs and annuals is similar in the control and tent sites but these values show considerable decreases, ranging from 60% to 82%, from the control figures in the tent roads, parking lot, and main roads (Table 20). The most abundant species is Euphorbia polycarpa, an herbaceous perennial. Other species present, all in only trace amounts, include S. arabicus in all categories except the main roads, Parafoxia linearis in the control, and Plantago insularis in all categories except the parking lot.

A total of 31.4% of the surface in the control is covered by the crustose lichen, Heppia lutosa (identified by Dr. H.D. Thiers, San Francisco State University). The crust is composed of two morphological forms identified here as "relief" and "flat" types. The total lichen cover progressively decreases in the disturbed categories in the following order: parking lot, 23%; tent sites, 32%; tent roads, 44%; main roads 83% (Table 20). Along with a decrease in total lichen cover, the ratio of relief to flat lichen types becomes progressively smaller in the following order: control (.82), main roads (.24), tent sites (.20), tent roads (.11), and parking lot (.08).

Camp Granite

The vegetative community at Camp Granite is similar to that at Camp Iron Mountain. A total of 6 shrub species were sampled here. The total density and cover values for perennial shrubs in the controls at these camps, although greater at Granite, are least compared with the controls of other camps. The vegetation of the control includes the following shrub species: L. tridentata, A. dumosa, Atriplex polycarpa, Opuntia echinocarpa, O. ramossisima, and Stephanomeria pauciflora (Tables 17,18). Like Iron Mountain, the shrubs are widely spaced with L. tridentata accounting for 5.7% of the total cover, and a cryptogamic crust occupies 43% of the intershrub ground surface.

The number of perennial shrubs is larger in the tent sites and parking lot as compared to the control, but is lower in the main roads. Density values differ from the control by the following percentages: tent sites, +46.1%; parking lot, +30.7%; main roads, -28.8% (Table 19). None of these differences in density are statistically different from the control (Fig. 32). Total shrub cover, on the other hand, is significantly decreased from the control in all categories of disturbance. Compared to a control value of 9.6%, percent decreases in disturbed areas are: tent sites, 53.1%; parking lot, 58.3%; main roads, 72.9% (Table 19). Reduction in cover is significant at the .05 level of probability in the tent sites and at the .01 level in the remaining two categories (Fig. 32).

As in disturbed areas of all camps, the portion of long-lived shrub species present is reduced and that of long-lived opportunistic shrub species is increased. Relative cover of the long-lived functional group is about half of that in the control in all three categories of disturbance. The relative cover of A. dumosa has doubled from the control in all disturbed categories and it is the dominant species in each of these categories. There are also slight increases in the proportion of cover that is provided by short-lived species in disturbed areas (Table 18, Fig. 33).

Annuals and herbs are greatly reduced in total density and cover in all disturbed categories at Camp Granite. Decreases in density range from 64% to 100% dropping from 5 plants per m^2 in the control to 1.8/ m^2 in main roads, and 1.1/ m^2 in tent sites; cover drops from 3.9% in the control to 2.2% in main roads and 0.2% in tent sites; only a trace amount of cover is present in the parking lot (Table 20). P. insularis is the only annual and supplies 0.2% of the cover in the control and tent sites with a trace amount present in the parking lot. Euphorbia polycarpa is the only herb and is the dominant species where it does occur, providing 3.7% of the cover in the control and the full 2.2% of cover in the main roads.

The total cover of lichen crust in the control is 43.4%. The percentage of lichen cover in the disturbed areas is: tent sites, 16%; parking lot, 21%; main roads, 50%. The ratio of relief to flat types of crust ranges from 1.5 in the control to .58, .49, and .40 in the main roads, parking lot, and tent sites, respectively.

DISCUSSION

The degree to which soil and vegetation characteristics have reassumed their pre-disturbance states is not evenly advanced at the different sites, nor is it always directly correlative with degrees of disturbance. Moreover, although direct comparison of the properties measured for control areas versus disturbed areas provides a measure of residual impacts, the actual trends and rates of change of some properties are more difficult to assess. For example, the ability of the soil to support vegetation may still be degrading, not recovering, where erosion remains accelerated. We begin this section with a discussion of residual effects of military base-camp establishment on soil and surface hydrology properties, and follow with effects on vegetation properties. The relationship between soil and vegetation recovery in disturbed camp areas is also discussed.

Figure 34 shows recording penetrometer Metzger values for all five camps combined. Compared to the control, values differ by the following percentages: tent sites, -36.2%; tent roads, -67.6%; parking lots, -74.1%; main roads, -81.5%. A clearly defined trend exists: soil compaction increases as the intensity of use increases. The Metzger values decrease logarithmically, which suggests that the limits of compactability for sandy desert soils are approached by repeated foot and light vehicle traffic.

In order of greatest to least amount of soil compaction detected in disturbed areas by the recording penetrometer, Camp Granite shows the highest (Metzger value= 103), followed by Iron Mountain, Ibis, new Clipper, then old Clipper. Comparatively higher Metzger values for controls do not always correlate with greater degrees of residual compaction. The new Clipper Camp has the second highest Metzger value of all camps (99) in the control, but the disturbed areas exhibit a lesser amount of compaction than two camps with somewhat lower Metzger values in their controls (Ibis and Iron Mountain). Assuming that the four camps, excluding new Clipper, underwent similar levels of impact in the disturbed areas, two variables may explain why the soils in the camps do not show similar levels of compaction: 1) the soils did not compact to similar levels initially because of differing soil characteristics at each camp; 2) soils have undergone different levels of recovery at each camp. Previous research indicates that the first variable provides the chief explanation for our results, and this topic will be discussed later in this section.

All disturbed categories at individual camps have statistically (p=.01) higher bulk density values in the 0-30 cm depth range than the respective controls, except for the tent sites at the two Clipper camps. Results for all camps combined show similar trends in disturbed areas as do penetrometer results (Fig 35). An increase in use-intensity is correlative with an increase in bulk density; values in the disturbed areas are statistically higher (p=.01) than control values in the 0-30 cm depth range by the following amounts: tent sites, 2.5%; tent roads, 5.6%; parking lots, 6.8%; main roads, 11.1%. Although density values for disturbed areas are statistically higher than control values, percent differences are much lower than Metzger values in the same comparison. Other studies have noted similar findings when contrasting bulk density and penetrometer results (Taylor and Gardner, 1963; Voorhees and others, 1978; Prose, 1985). However, the bulk density method does hold an important advantage over the penetrometer when measuring compaction in highly-compacted soils in that compaction can be quantified in soils that are too stiff to allow penetration with a penetrometer.

When broken down into 10 cm intervals, it is apparent that density increases in disturbed areas are largest in the 0-10 cm depth interval. This is despite the presence of a surface vesicular layer of weakly consolidated silt as much as 4 cm thick, so that the 0-10 cm sample only includes 1/2 to 3/4 of the compacted zone in disturbed plots. The 20-30 cm depth interval is the least-compacted of the three intervals in disturbed areas; 58% of the plots show significant increases in density over control values, and most of these increases occur in the highly compacted main roads and tank parking lots. The effective zone of compaction, then, is generally located in a depth range of about 3 to 20 cm, though it may extend to at least 30 cm in areas of high use-intensity.

Both penetrometer and bulk density results show that Camp Granite soils exhibit the greatest amount of soil compaction of all four camps. This may in part be due to the looseness of the soil, but a more important factor is that the soils probably underwent a greater amount of compaction initially because of their particle-size distribution. Camp Granite soils are classified as sands (sand and/or coarser particles comprise 87% of the total weight percent), and sands are more compactable than finer soils (Veihmeyer and Hendrickson, 1948). In addition, Bodman and Constantin (1965) found that soils containing a wide distribution of particle sizes, well-graded ones, will compact more than poorly-graded ones because the fine particles fill in the voids between coarser ones. Though predominantly comprised of sand, Camp Granite soils are better graded than the other camp soils (Fig 36). Camp Ibis and Iron Mountain soils are coarser (Fig. 37), and soils at the two Clipper Camps contain mostly medium and fine sands and very little gravel (Figs. 39 and 40). The order of relative compaction levels between camps is consistent with findings on the relationship of particle-size distribution and soil compaction.

Another factor that may influence degrees of soil compaction is the shape of individual soil particles. Sands that contain a high percentage of angular particles undergo relatively higher levels of compaction (Veihmeyer and Hendrickson, 1948). Camps Granite and Iron Mountain, both exhibiting relatively high levels of soil compaction in disturbed areas, are on alluvium composed of angular materials derived by mechanical weathering of granitic rocks. The other camps contain granitic source materials as well, but in lower proportions and exhibiting a lower degree of angularity because of their distal location from source mountain ranges.

It is possible that the disturbed soils at the camps have recovered slightly from initial levels of compaction, and if so, rates of recovery may vary because of differing soil properties. Little research has been done on this subject, but a few studies indicate that relatively coarse soils recover more rapidly than finer ones (Webb and Wilshire, 1980; Power, 1974). This may be offset because coarser soils undergo greater levels of compaction, as our results show that the coarser soils are still more compacted than finer ones after 40 years. In a more general sense, recovery time of compacted desert soils is very long compared to soils in regions with wetter climates. Webb and Wilshire (1980) found soils are still significantly compacted in a trampled area of a Nevada mining town that was abandoned 55 years ago, whereas high levels of compaction induced by repeated passages of farm machinery in the northern U.S. can be alleviated over one winter season (Gill, 1971; Kucera and Promersberger, 1960). Soils in regions with wet climates undergo repeated cycles of wetting and drying which serve to loosen compacted soils by volume expansion (Dickerson, 1976), especially where temperatures are low enough to cause freezing and thawing during the winter. In our study area, however, the annual precipitation rate is one of the lowest in the U.S., and winter temperatures rarely drop to a level that causes freezing. In addition, vegetation density is usually correlative with amount of rainfall in a given region; only 7-18% of the ground surface at the camps is occupied by perennial plants. Soil loosening processes in arid regions are mainly related to the root expansion of the relatively sparse vegetative cover and the burrowing activity of animals, but compaction and other alterations of soil characteristics at the camps have so affected many of the variables that are prerequisite to plant and animal life that soil loosening in the disturbed areas is significantly impaired.

Water infiltration rates are reduced as a result of soil compaction (for example, Iverson and others, 1981). Much of the rainfall that normally infiltrates the soil in arid regions collects in depressions on the surface of compacted zones and evaporates quickly, or runs off into wash channels. Depending on soil type, ground slope, and level of compaction, surface drainage characteristics may consequently be significantly altered. Channel transects at Camp Ibis show that compaction levels in the tent areas and parking lots have caused a doubling in the number of channels as compared to the control. On the other hand, there are 50% less channels in the parking lot than the control at Iron Mountain, suggesting that uniformly extreme compaction may induce sheet runoff. Since vegetation in the Mojave Desert is much denser adjacent to wash channels than on interchannel surfaces because of water availability, any changes in the drainage system will affect vegetative growth patterns. Our vegetation results, which are discussed further along in this section, reflect this relationship.

Rainfall does infiltrate extremely compacted soils, though at a rate much lower than normal. Drainage of H_2O through the soil profile to the calcic K horizon and capillary loss to the surface also take place at a slower rate, as shown by higher H_2O levels in most disturbed camp soils than the controls. This could explain why increased levels of calcium carbonate are found in some of the highly compacted areas at the camps. Carbonate enters the soil as a solute in rainwater, and a high percentage of it percolates through the soil profile and precipitates at the maximum depth of H_2O percolation, the K horizon (Gile and others, 1966). A small amount accumulates throughout the upper soil profile as well. The detection of slightly increased levels of carbonate in some of the disturbed areas indicates that compaction is slowing H_2O percolation rates enough to cause increased carbonate precipitation in the upper soil profile. Gradual carbonate cementation may then be expected to reduce infiltration rates in compacted soils more rapidly than in undisturbed soils with time.

Increased surface runoff in compacted areas promotes accelerated soil removal rates, as is shown by the greater volume of sediments deposited downslope from tent areas compared to minimally-disturbed areas at Camp Ibis. This effect is compounded in areas stripped of vegetation, such as all the disturbed plots at the camps. Accelerated soil erosion is probably a significant factor contributing to the persisting alteration of vegetation at the camps, especially in the camp roads where 10-15 cm of soil was initially removed during camp construction. Charley and Cowling (1968) found that a loss of 10 cm of soil in an arid region of Australia caused a serious depletion of nutrients essential to plant growth, namely nitrogen, phosphorus, and organic carbon.

In summary, soil compaction is a direct result of the establishment and use of the base-camps. Significant levels of compaction persist in areas that sustained a wide range of use-intensities after a 40-year recovery period.

The amount of residual compaction is correlative with soil particle size and shape distributions. Soil compaction and road construction have caused changes in surface drainage patterns, H_2O infiltration/runoff rates, and H_2O and carbonate transport mechanics through the soil profile. Alteration of these soil characteristics is causing significant interference in the reestablishment of vegetation to pre-disturbance conditions, which in turn, is slowing the recovery of soil characteristics.

Recovery of the perennial shrubs in disturbed areas can be viewed from the perspective of quantitative indices such as total density and total percent cover. The density of the perennial shrubs in disturbed areas differs from the control areas by the following average amounts (ranges are given in parentheses): tent sites, +92.1% (-21.0 - +435.3); tent roads, -23.0% (-50.6 - +3.1); parking lot, +63.0% (-60.2 - +385.4%); main roads, -54.2% (-66.9 - -28.8). When the density of the shrubs in disturbed areas is statistically compared to controls, 53% of the disturbed areas can be considered comparable to the controls. The recovered areas include: 4 tent sites (all camps except Iron Mt.); 2 tent roads (camps old Clipper and Iron Mountain); 3 parking lots (camps Ibis, old Clipper and Granite); one main road (camp Granite). The tent sites and parking lot at Camp Iron Mountain, show significant (p=.01) increases in shrub density over the control while the remaining 7 categories show significant reductions (Fig. 32).

As the ranges of the average differences in total density between control and disturbed areas indicate, the vegetative response in a given category of disturbance tends to be quite variable from camp to camp. In general, however, tent sites exhibit the greatest degree of recovery, followed by parking lots, tent roads, and main roads. This response is different from that observed in relation to soil compaction in which compaction increases as intensity of use increases (i.e. parking lots are more compacted than tent roads). Overall, in terms of shrub density the disturbed categories at Camp Granite exhibit the greatest degree of recovery, followed by old Clipper, Ibis, new Clipper and Iron Mountain.

In terms of total shrub cover, which is considered to be of greater ecological significance than density (Daubenmire 1968), 32% of the disturbed areas are recovered. Cover of disturbed areas differs from the controls by the following average amounts: tent sites, -31.9% (-53.1 - +1.5); tent roads, -53.2% (-83.6 - -35.7); parking lots, -27.4% (-64.1 - +40.3); main roads, -69.5% (-88.0 - -57.6). The parking lot at Iron Mountain shows a significant (p=.05) increase in shrub cover while the other 12 areas of disturbance show significant reductions. The categories of disturbance that are comparable to the controls include 3 tent sites (camps Ibis, new Clipper, Iron Mountain), one tent road (camp old Clipper), and two parking lots (camps Ibis and old Clipper).

When the categories for all 5 camps are combined, reductions from the controls of the perennial shrub cover are not as variable for a given category of disturbance as are differences in density. The disturbed areas follow in the same sequence as density when the average amount of reduction in shrub cover is examined. Overall, old Camp Clipper is the most recovered, followed by Ibis, Iron Mountain, new Clipper, and Granite. These results are generally consistent with our soil compaction measurements which indicate that disturbed soils at Camp Granite are the most compacted and those at old Clipper the least compacted of the camps.

Indices which reflect the quality of the vegetation, such as the type of dominant plants, can also be considered in the evaluation of recovery. When the character of the vegetation is considered, recovery of the disturbed areas is less extensive than the total density and total cover data indicate. Long-lived shrubs are dominant with regard to both relative and absolute coverage in the controls of all camps. The dominant species in this functional group is L. tridentata. All categories of disturbance, however, show an average overall reduction of 77% in the total cover contributed by long-lived species. When the analysis of recovery encompasses the proportion of vegetative cover provided by the long-lived functional group as well as the absolute amount of shrub cover, only 3 of 19 categories of disturbance can be considered recovered; these recovered categories are the tent roads and parking lot both at camp old Clipper and the tent sites at new Clipper. Although the total vegetative cover in these three sites is less than in their respective controls, the difference is not statistically significant (Fig. 32). Moreover, as in the control, the long-lived shrub L. tridentata is the dominant species. However, even in two of these recovered areas, L. tridentata is dominant by a narrow margin due to increases in the relative cover of A. dumosa that are 2 - 3 times greater than in the controls.

The degree of revegetation in the camps appears in part to be related to the manner in which the vegetation was originally removed and the subsequent intensity of use. The main roads in all of the camps were cleared of vegetation with graders, and where the surface was dissected, the depth of grading cuts well below root crown level. Main roads also recieved the greatest amount of use, and main roads show the highest reduction in total shrub cover and density compared to other use-categories throughout the camps.

Although the tent sites, tent roads and parking lots were all cleared by soldiers using hand tools, tent sites recieved the least amount of subsequent use. Four of the five tent sites are recovered in terms of shrub density and they account for half of all sites where the total amount of vegetative cover is not significantly reduced. Furthermore, tent site soils exhibit the least amount of compaction of any of the disturbed sites. Another illustration of the relationship between intensity of use and recovery is old Camp Clipper, which, abandoned shortly after construction, was the least used of all camps. Disturbed areas show the least amount of soil compaction and, overall, show a greater degree of vegetative recovery than similarily disturbed areas at more heavily used camps.

Additional factors are influencing the revegetation process. Parking lots were highly impacted and yet several do not show significant reductions from controls in the total shrub cover. One of these parking lots is that of little-used old Clipper camp. This camp is in the bottom of a valley that has a large catchment and probably recieves a larger volume of runoff than other camps. This may help explain the high degree of shrub recovery in this parking lot as well as the nearby tent roads. The Camp Ibis parking lot, also recovered in terms of shrub density and total cover, borders the control and is therefore close to a relatively abundant supply of seeds. In addition, wash channel transect data at Ibis indicate that the number of channels in the parking lot and tent sites (also recovered) is double that of the control. At camp Iron Mountain the channel density in the parking lot is half that in the control and this site shows a significant increase in the density and cover of Hymenoclea salsola. Reduction in channel frequency enhances sheet-flow of runoff thus creating environmental conditions favorable to this short-lived species which is typically confined to washes.

Previous work by Taylor and Gardner (1963), Grimes and others (1975), Taylor and Burnett (1964), Veihmeyer and Hendrickson (1948), and Voorhees and others (1978) have shown that there are limiting values of soil resistance and bulk density above which penetration of the roots of agricultural crops is greatly restricted or halted altogether. Webb and Wilshire (1980) cite compaction as a major limiting factor to the reestablishment of long-lived desert perennials. Lathrop (1983) combined data from camps Ibis and Clipper and found that the vegetation of the roadways suffered the greatest degree of negative impact followed by tank tracks and then tent sites. He suggested that this is a function of the amount of initial compaction with the roadways receiving the greatest intensity of use and the tent areas the least. To assess the influence of soil compaction on vegetative recovery in our study area, we employ Metzger values and soil bulk density results as indices of compaction. The total cover of all perennial shrubs and the total cover by functional group were used as indices of the degree of recovery of different types of vegetation in each disturbed site. Metzger values and bulk density were then plotted against shrub cover (Figs. 41a-f & 42). The comparisons show that Metzger value decreases or bulk density increases are not always correlative with decreases in total vegetative cover. In general, however, the tent sites exhibit the least amount of compaction and the least amount of reduction in total vegetative cover; the main roads display the largest amount of compaction and also the greatest amount of cover reduction; the parking lots and tent roads are more variable. The latter two are highly compacted yet may support as much or more vegetation than the controls. That the roots of some plants have been able to penetrate soils in disturbed areas where Metzger values are decreased by as much as 80% over control values and bulk density values are up to 11% higher, indicates it is possible for local soil conditions to exist which allow for the establishment of certain types of vegetation even in a highly compacted area. A. dumosa is the dominant species in most disturbed areas. In all tent sites, and in some parking lots (Ibis, Granite) and tent roads (old Clipper and Iron Mountain), the total density and cover of this species are equal to or greater than its density and cover in the controls. Furthermore, Camp Granite soils are the most compacted of all camp soils yet the shrub density in all disturbed areas is comparable to the density of shrubs in the control due to the presence of A. dumosa. At minimum to moderate, and in some instances even high levels of compaction, A. dumosa seems to have little difficulty recolonizing these sites. Short-lived shrub species, although they are generally minor components of the total vegetative cover, are also more numerous and provide greater cover on disturbed sites than in the controls of the camps where they occur. The abundance of these two groups of plants in disturbed areas is probable due to local changes in the microwatershed habitat which make conditions more favorable to seedling establishment.

In contrast to increases in density and cover of the long-lived opportunistic and short-lived species, L. tridentata is still markedly reduced after 40 years. The lack of recovery of L. tridentata and other long-lived species is probably related to life-history strategies as well as soil compaction. The number of seedling establishments necessary to maintain adult populations of long-lived species is very small and, indeed, L. tridentata follows a stategy of gradual, slow establishment of new individuals as evidenced by its low rate of seed germination and the extremely low survival rate of seedlings (Went and Westergaard 1949; Barbour 1968, 1969; Sheps 1973). This, combined with relatively short seed dispersal distances (Chew and Chew, 1965), makes for a slow rate of recovery following disturbance; L. tridentata has been found to demonstrate a negative response up to at least 60 years following disturbance (Johnson and others, 1975). On the other hand, short-lived plants are adapted to rapid, large-scale establishment via enormous seed production and highly efficient seed dispersal mechanisms. The predominant mode of reproduction for A. dumosa is also via seeds (Vasek, 1983) and this long-lived opportunistic species exhibits the pioneering capabilities of short-lived species. As a result of this ability to recolonize quickly, these two functional groups tend to show a positive response on minimally disturbed surfaces and/or in some areas where there have been changes in surface hydrologic characteristics.

Aside from an advantageous reproductive strategy, A. dumosa may also be better adapted than L. tridentata to the altered physical and chemical properties of the disturbed soils. For example, as a consequence of increased bulk density of soils, the rate of water infiltration is reduced (Luckenbach, 1975; Wilshire and others, 1978; Webb and Wilshire, 1980; Iverson and others, 1981) as is the interparticle space available for oxygen which is necessary for the respiration process essential in the uptake of nutrients and water by plant roots (Lunt and others, 1973; Hausenbuiller, 1978). In addition, important nutrients, such as nitrogen, accumulate in the upper layers of soil beneath the vegetation from which input is continually derived (Hausenbuiller, 1978; Garcia-Moya, 1970; Romney and others, 1973; Wallace and others, 1978). Removing the vegetation and this top layer of soil, directly by grading or indirectly by removal of the vegetation which effectively increases wind and water erosion of the soil, exposes nutrient depleted soils while simultaneously eliminating the major refueling source from the system. El-Ghonemy and others (1980) found that vegetative groupings dominated by A. dumosa showed significant correlation with areas of low soil moisture retention and that these groupings were also on soils poor in nitrogen. In addition, Lunt and others (1973) found the amount of soil oxygen required for root growth in A. dumosa was not as high as that required by L. tridentata. Competition between A. dumosa and L. tridentata for soil moisture (Fonteyn and Mahall, 1981) may further arrest the re-establishment of L. tridentata seedlings in areas now dominanted by A. dumosa.

In summary, 10 of the 19 disturbed categories can be considered comparable to the controls with regard to perennial shrub densities (53%) and 6 of the 19 can be considered recovered in terms of total cover (32%). When the relative proportion of long-lived shrub cover is included in the analysis of recovery, only 3 of these 6 sites (16% of total 19) are still comparable to their controls.

While the species and actual density and cover figures vary from camp to camp, the re-establishment of perennial shrubs tends to be strongest on sites which sustained the least amount of soil compacting forces. Even in highly compacted areas, however, short-lived and long-lived opportunistic species have become re-established due to a combination of proximity of the disturbed site to a seed bank, changes in surface hydrology characteristics, and a reproductive strategy which enables these species to recolonize disturbed areas relatively quickly.

Overall, all categories of disturbance remain markedly different from their respective controls after 40 years. The differences are reflected in a reduction in the density and cover of long-lived species in all categories of disturbance, an increase in short-lived and long-lived opportunistic species in most minimally to moderately disturbed areas, and significant reductions of all shrubs in areas of maximum disturbance.

The populations of annuals and herbaceous perennials at our study sites are sparse, but together these plants generally display considerable reductions in both density and cover in disturbed areas of all camps except old Clipper. At old Camp Clipper, the tent sites and tent roads are both comparable to the control and the parking lot has nearly twice the density and cover of annuals. The annual Plantago insularis is dominant in the control whereas the introduced annual grass Schimus arabicus is dominant in these disturbed areas, showing densities 3-4 times the control level. The predominance of S. arabicus is probably related to the proximity of these areas to a major wash channel with the parking lot in particular showing evidence of past flooding. The degree of reduction of the microflora does not correlate with the intensity of use. Vasek (1983) and Johnson and others (1975) suggest that native annuals of the desert ecosystem tend to be integrated members of established creosote communities rather than being of the purely pioneer status ascribed to annuals of temperate ecosystems. The abundance of the few native annual species and herbs observed in the controls compared to their near absence in disturbed areas supports this conclusion.

The paucity of annuals and herbaceous perennials on disturbed sites may also be due to modification of the soils atmosphere that results in conditions unfavorable to seed germination in even minimally compacted areas. For germination to occur, specific soil temperature and moisture conditions are required (Went and Westergaard, 1949; Went 1955; Juhren and others 1956; Beatly, 1974b; Luckenbach, 1975). Changes in the soils atmosphere brought about by compaction, such as surface ponding, reduced infiltration rates, and an extension of the diurnal temperature range (Wilshire and others, 1978), may obstruct the germination of seeds.

An average of 37.4% of the intershrub ground surface in the controls of camps Granite and Iron Mountain is covered with the lichen crust, Heppia lutosa. This species is a member of the Heppiaceae family which occurs widely on calcareous soils in arid parts of the southwestern United States (Wetmore, 1970). Due to a slow growth rate it is primarily found on relatively stable surfaces (Wetmore, 1970), and it usually forms small mounds which give the ground surface a "warty" relief. Such relief inhibits channelization of runoff and reduces surface wind and water velocity thereby guarding against wind and water erosion of the underlying soil (Wilshire, 1983). Not only do populations of soil-consolidating lichens such as the Heppiaceae serve to stabilize the soil (Shields and others, 1957; Rogers and Lange, 1971), they also represent a continually renewable supply of soil nitrogen (Shields and others, 1957; Rogers and Lange, 1966; Wetmore, 1970). These cryptogamic crusts are therefore an important element in the recovery of arid lands.

Recovery of the cryptogam cover to predisturbance conditions in the disturbed areas at the two camps has been minimal after 40 years due to naturally slow growth rates and adverse surface conditions. The areas of disturbance in these camps show an average reduction of 38% (range=16%-83%) in the total amount of lichen crust when compared with the controls. In addition, nearly all of the crust present in disturbed areas has a grayish, flat texture as opposed to the dark hummocks in the controls. The reduction in relief and the increase in flat types of crust in disturbed areas is reflected in the R/F ratio in Table 20.

Time estimates for recovery of the creosote bush community

Larrea tridentata is the predominant species of the mature creosote bush community of the Mojave Desert (Shreve, 1942; Johnson and others, 1975; Vasek and Barbour, 1977; El-Ghonemy and others, 1980). However, once eliminated from an area, reestablishment of this long-lived species is much slower than other species due to the low rate of seedling recruitment (Barbour, 1968, 1969; Sheps, 1973; Fonteyn and Mahall, 1981). Because L. tridentata is the limiting factor in vegetative recovery, estimates of the time required for recovery of this community should be keyed to the recovery of this species.

In order to estimate the number of years yet required for the density of *L. tridentata* in disturbed areas to be the same as in the controls, the natural rate of seedling recruitment had to first be determined. To do this it was necessary to distinguish between those individuals that may be residual, those that may have resprouted from preexisting root crowns, and those that are new individuals. This was done by noting during the sampling whether or not an individual had one distinct point of entry into the ground. Based on Vasek's (1980) description of the cloning process in creosote, in which several functionally separate ramets are reached at 40-90 years of age, it was assumed that a single stem denoted a seedling recruit 40 years or less in age. If an individual was composed of a clump of several closely associated stem segments it was considered a residual plant or a root crown resprout. The number of years to recover via natural seedling recruitment was then estimated according to the following formula:

$$A = \frac{\text{\# new individuals per unit area}}{\text{40 years}} \qquad B = \text{\# individuals in control} - \text{\# in disturbed area not new}$$

$$B/A - 40 = \text{\# years yet required to attain control density}$$

Our data indicates that recovery of *L. tridentata* densities in disturbed areas to control densities may require from 48 years to over 500 years (Table 21). However, the undisturbed community is commonly composed of asexually-derived clonal rings of *L. tridentata* which form over thousands of years (Vasek and others, 1975; Sternberg, 1976; Vasek, 1980). Therefore, even if control densities are established in disturbed areas within the time frame predicted by our data, recovery to original vegetative structure could be on the order of 1500 to 3000 years as estimated by Vasek and others (1975a), if at all.

end

REFERENCES

Bachman, G. O., and Machette, M. N., 1977, Calcic soils and calcretes in the southwestern United States: U. S. Geological Survey Open File Report, no. 77-794, 163 p.

Barbour, M. G., 1968, Germination requirements of the desert shrub *Larrea divaricata*; Ecology, v. 49, p. 915-923.

Barbour, M. G., 1969, Age and space distribution of the desert shrub *Larrea divaricata*: Ecology, v. 50, p. 679-685.

Beatley, J. C., 1974b, Phenological events and their environmental triggers in Mojave Desert ecosystems: Ecology, v. 55, p. 856-863.

Bodman, G. B., and Constantin, G. K., 1965, Influence of particle size distribution in soil compaction: Hilgardia, v. 36, no. 15, p. 567-591.

Brower, J. E., and Zar, J. H., 1977, Field And Laboratory Methods For General Ecology: Dubuque, Iowa, Wm. C. Brown Co., 194 p.

Brum, G. D., Boyd, R. S., and Carter, S. M., 1980, Recovery rates and rehabilitation of powerline corridors, *in*, R. H. Webb and H. G. Wilshire (eds): Environmental Effects of Off-Road Vechiles: New York, Springer-Verlag, p. 303-314.

Campbell, R. C., 1974, Statistics for Biologists, 2nd ed.: New York, Cambridge University Press, 385 p.

Carter, L. M., 1967, Portable recording penetrometer measures soil strength profiles: Agricultural Engineering Journal, no. 48, p. 348-349.

Charley, J. L., and Cowling, S. W., 1968, Changes in soil nutrient status resulting from overgrazing and their consequences in plant communities of semi-arid areas: Proceedings of the Ecological Society of Australia, no. 3, p. 28-38.

Chew, R. M., and Chew, A. E., 1965, The primary productivity of a desert shrub (*Larrea tridentata*) community: Ecological Monographs, v. 35, p. 355-375.

Daniel, W.W., 1978, Biostatistics, 2nd ed.: New York, John Wiley & Sons, 504 p.

Daubenmire, R., 1959, A canopy-coverage method of vegetational analysis: Northwest Science, v. 33, p. 43-64.

Daubenmire, R., 1968, Plant Communities: New York, Harper and Row, 300 p.

Day, P. R., 1965, Particle fractionation and particle-size analysis, *in*, C. A. Black (ed.): Methods of Soil Analysis: Wisconsin, American Society of Agronomy, Inc., p. 562-566.

Dickerson, B. P., 1976, Soil compaction after tree-length skidding in northern Mississippi: Journal of the Soil Science Society of America, v. 40, p. 965-966.

Dreimanis, A., 1961, Quantitative gasometric determination of calcite and dolomite by using Chittick apparatus: Journal of Sedimentary Petrology, v. 32, no. 3, p. 520-529.

El-Ghonemy, A. A., Wallace, A., and Romney, E. M., 1980, Socioecological study of the natural vegetation in the Northern Mojave-Great Basin desert interface: Great Basin Naturalist Memoirs, no. 4 Bringham Young University, p. 71-88.

Fonteyn, P. J., and Mahall, B. E., 1981, An experimental analysis of structure in a desert plant community: Journal of Ecology, v. 69, p. 883-896.

Frank, P. W., 1968, Life histories and community stability: Ecology, v. 49, p. 355-356.

Garcia-Moya, E., and McKell, C. M., 1970, Contribution of shrubs to the nitrogen economy of a desert-wash plant community: Ecology, v. 51, p. 81-88.

Gile, L. H., Peterson, F. F., and Grossman, R. B., 1966, Morphological and genetic sequences of carbonate accumulation in desert soils: Soil Science, v. 101, p. 347-360.

Gill, W. R., 1971, Economic assessment of soil compaction, in, K. K. Barnes, W.M. Carlton, H. M. Taylor, R. I. Throckmorton, G. E. Vandenberg (eds.): Compaction of Agricultural Soils: St. Joseph, Michigan, American Society of Agricultural Engineering.

Greig-Smith, P., 1983, Quantitative Plant Ecology, 3rd ed.: Berkeley, University of California Press, 359 p.

Grimes, D. W., Miller, R. J., and Wiley, P. L., 1975, Cotton and corn root development in two field soils of different strength characteristics: Agronomy Journal, v. 67, p. 519-523.

Hausenbuiller, R. L., 1978, Soil Science Principles and Practices, 2nd ed: Dubuque, Iowa, Wm. Brown Co. Publishers, 611 p.

Iverson, R. M., Hinckley, B. S., Webb, R. M., and Hallet, B., 1981, Physical effects of vehicular disturbances on arid landscapes: Science, v. 212, no. 22, p. 915-917.

Johnson, H. B., Vasek, F. C., and Yonkers, T., 1975, Productivity, diversity and stability relationships in Mojave Desert roadside vegetation: Bulletin of the Torrey Botanical Club, v. 102, p. 106-115.

Juhren, M., Went, F. W., and Phillips, E., 1956, Ecology of desert plants. 4. Combined field and laboratory work on germination of annuals in the Joshua Tree National Monument, California: Ecology, v. 37, p. 318-330.

Kay, B. L., and Graves, W. L., 1980a, History of revegetation studies in the California deserts, in, R. H. Webb and H. G. Wilshire (eds): Environmental Effects of Off-Road Vehicles: New York, Springer-Verlag, p. 315-324.

Kay, B. L., and Graves, W. L., 1980b, Revegetation and stabilization techniques for disturbed desert vegetation, in, R. H. Webb and H. G. Wilshire (eds.): Environmental Effects of Off-Road Vehicles: New York, Springer-Verlag, p. 325-340.

Kershaw, K., 1973, Quantitative and Dynamic Plant Ecology, 2nd ed.: London, Edward Arnold, 308 p.

Kucera, H. L., and Promersberger, W. J., 1960, Soil compaction... a North Dakota problem?: North Dakota Resource Bulletin, v. 21.

Lathrop, E. W., and Archbold, E. F., 1980a, Plant response to Los Angeles aquaduct construction in the Mojave Desert: Environmental Management, v. 4, no. 2, p. 137-148.

Lathrop, E. W., and Archbold, E. F., 1980b, Plant response to utility construction in the Mojave Desert: Environmental Management, v. 4, no. 3, p. 215-226.

Lathrop, E. W., 1983, Recovery of perennial vegetation in military maneuver areas, in, R. H. Webb and H. G. Wilshire (eds.): Environmental Effects of Off-Road Vehicles: New York, Springer-Verlag, p. 153-166.

Luckenbach, R. A., 1975, What ORV's are doing to the desert: Fremontia, V. 2, p. 3-11.

Lunt, O. R., Lety, J., and Clark, S. B., 1973, Oxygen requirements for root growth in three species of desert shrubs: Ecology, v. 54, p. 1356-1362.

Mueller-Dombois, D., and Ellenberg, H., 1974, Aims and Methods of Vegetation Ecology: New York, John Wiley and Sons, 547 p.

Munz, P. A., 1974, A Flora of Southern California: Berkeley, University of California Press, 1086 p.

Power, W.E., 1974, Effects and observations of soil compaction in the Salem district: U. S. Bureau of Land Management Technical Note, no. T/N-256, 12 p.

Prose, D. V., 1985, Long-term effects of military manuevers on some soils of the Mojave Desert: Environmental Geology, in press.

Rogers, R. W., and Lange, R. T., 1966, Nitrogen fixation by lichens of arid soil crusts: Nature, v. 209, no. 5018, p. 96-97.

Rogers, R. W., and Lange, R. T., 1971, Lichen populations on arid soil crusts around sheep watering places in S. Australia: Oikos, v. 22, p. 93-100.

Romney, E. M., Hale, V. Q., Wallace, A., Lunt, O. R., Childress, J. D., Alexander, G. V., Kinnear, J. E., and Ackerman, T. L., 1973, Some characteristics of soil and perennial vegetation in northern Mojave Desert areas of the Nevada Test Site: Springfield, Va., USAEC Report, UCLA #12-916, Federal Scientific and Technical Information Clearinghouse, 62 p.

Sheps, L. O., 1973, Survival of _Larrea tridentata_ S & M seedlings in Death Valley National Monument, California: Israel Botany, v. 22, p. 8-15.

Shields, L. M., Mitchell, C., and Drouet, F., 1957, Alga- and lichen-stabilized surface crusts as soil nitrogen sources: American Journal of Botany, v. 44, p. 489-498.

Shreve, F., 1942, The desert vegetation of North America: Botanical Review, v. 8, p. 31-33.

Sternberg, L., 1976, Growth forms of _Larrea tridentata_: Madrono, v. 23, p. 408-417.

Taylor, H. M., and Gardner, H. R., 1963, Penetration of cotton seedling taproots as influenced by bulk density, moisture content, and strength of soil: Soil Science, v. 96, p. 153-156.

Taylor, H. M., and Burnett, E., 1964, Influence of soil strength on the root growth habits of plants: Soil Science, v. 98, p. 174-180.

Thorne, R. F., 1976, The vascular plant communities of California, _in_, J. Latting (ed.): Plant Communities of Southern California, Symposium Proceedings, California Native Plant Society, no. 2, p. 1-31.

Vasek, F. C., Johnson, H. B., and Eslinger, D. H., 1975a, Effects of pipeline construction on creosote bush scrub vegetation of the Mojave Desert: Madrono, v. 23, p. 1-13.

Vasek, F. C., Johnson, H. B., and Brum, G. D., 1975b, Effects of power transmission lines on vegetation of the Mojave Desert: Madrono, v. 23, p. 114-130.

Vasek, F. C., and Barbour, M. G., 1977, Mojave Desert scrub vegetation, _in_ M. G. Barbour and J. Major (eds.): Terrestrial Vegetation of California: New York, John Wiley & Sons, 1002 p.

Vasek, F. C., 1980, Creosote bush: Long-lived clones in the Mojave Desert: American Jounal of Botany, v. 67, p. 246-255.

Vasek, F. C., 1983, Plant succession in the Mojave Desert: Crossosoma, v. 9, p. 1-23.

Veihmeyer, F. J., and Hendrickson, A. E., 1948, Soil density and root penetration: Soil Science, v. 65, p. 487-493.

Vorhees, W. B., Senst, C. G., and Nelson, W. W., 1978, Compaction and soil structure modification by wheel traffic in the Northern corn belt: Journal of the Soil Science Society of America, v. 42, p. 344-349.

Wallace, A. R., Romney, R. M., and Hunter, R. B., 1978, Nitrogen cycle in the Northern Mojave Desert: Implications and Predictions, _in_, N. E. West and J. J. Skujins (eds.): Nitrogen in Desert Ecosystems: Pennsylvania, Dowden, Hutchinson and Ross, Inc., p. 207-218.

Wallace, A., and Romney, E. M., 1980, The role of pioneer species in revegetation of disturbed desert areas: Great Basin Naturalist Memoirs, no. 4 Brigham Young University, p. 31-33.

Webb, R. H., and Wilshire, H. G., 1980, Recovery of soils and vegetation in a Mojave Desert ghost town, Nevada, U.S.A.: Journal of Arid Environments, v. 3, p. 1-15.

Went, F. W., and Westergaard, M., 1949, Ecology of desert plants. 2. The effect of rain and temperature on germination and growth: Ecology, v. 30, p. 1-13.

Went, F. W., 1955, The ecology of desert plants: Scientific American, v. 192, p. 68-75.

Wetmore, C. M., 1970, The lichen family Heppiacea in North America: Annals Missouri Botanical Garden, v. 57, p. 158-209.

Wilshire, H. G., and Nakata, J. K., 1976, Off-road vehicle effects on California's Mojave desert: California Geology, v. 29, no. 6, p. 123-132.

Wilshire, H. G., Nakata, J. K., Shipley, S., and Prestegaard, K., 1978, Impact of vehicles on natural terrain at seven sites in the San Francisco Bay Area: Environmental Geology, v. 2, no. 5, p. 295-319.

Wilshire, H. G., 1983, The impact of vehicles on desert soil stabilizers, <u>in</u>, R. H. Webb and H. G. Wilshire (eds.): Environmental Effects of Off-Road Vehicles: New York, Springer-Verlag, p. 31-48.

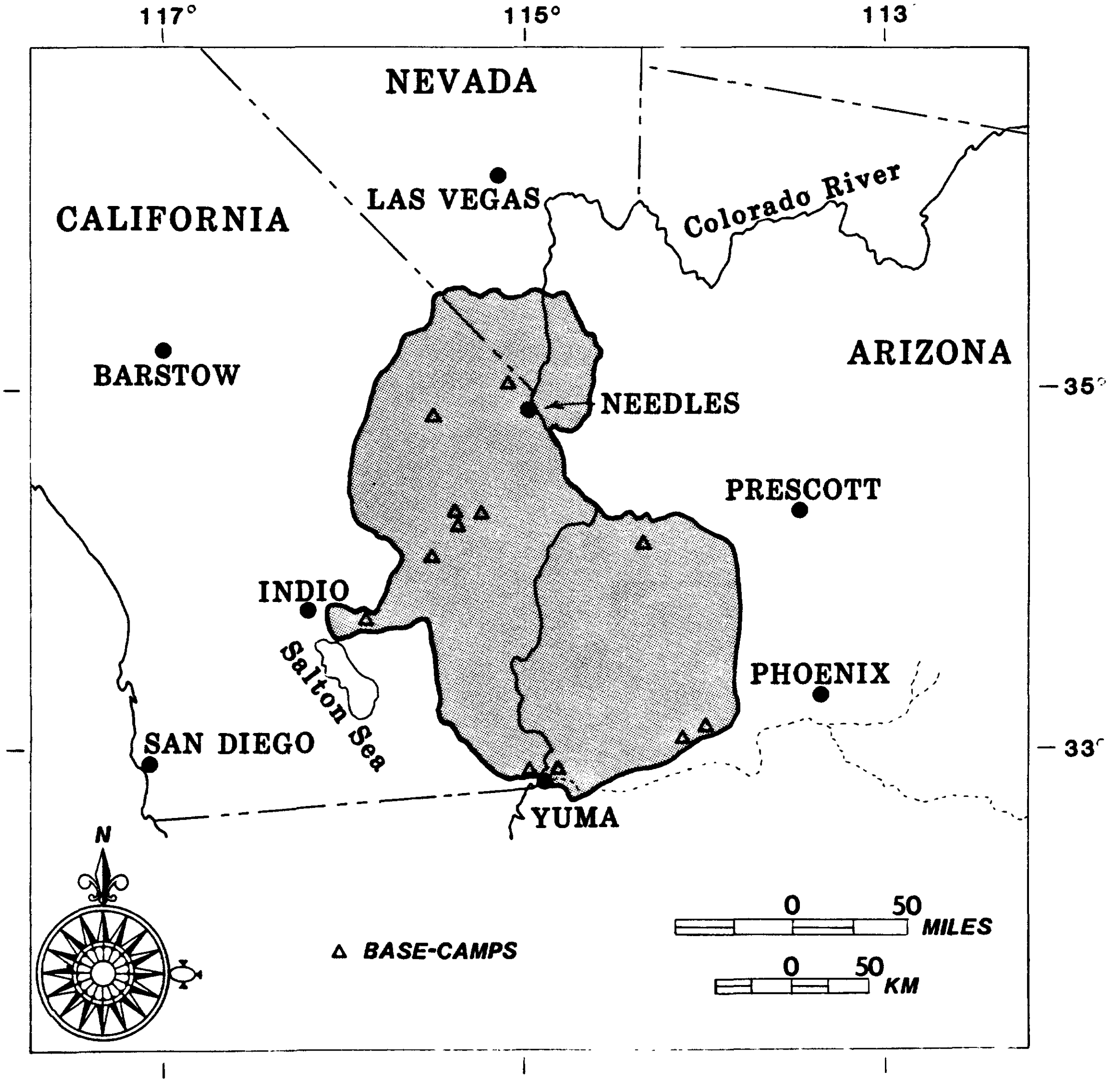


FIGURE 1. Desert Training Center, 1942-1944.

FIGURE 2. Recent aerial view of Camp Granite.

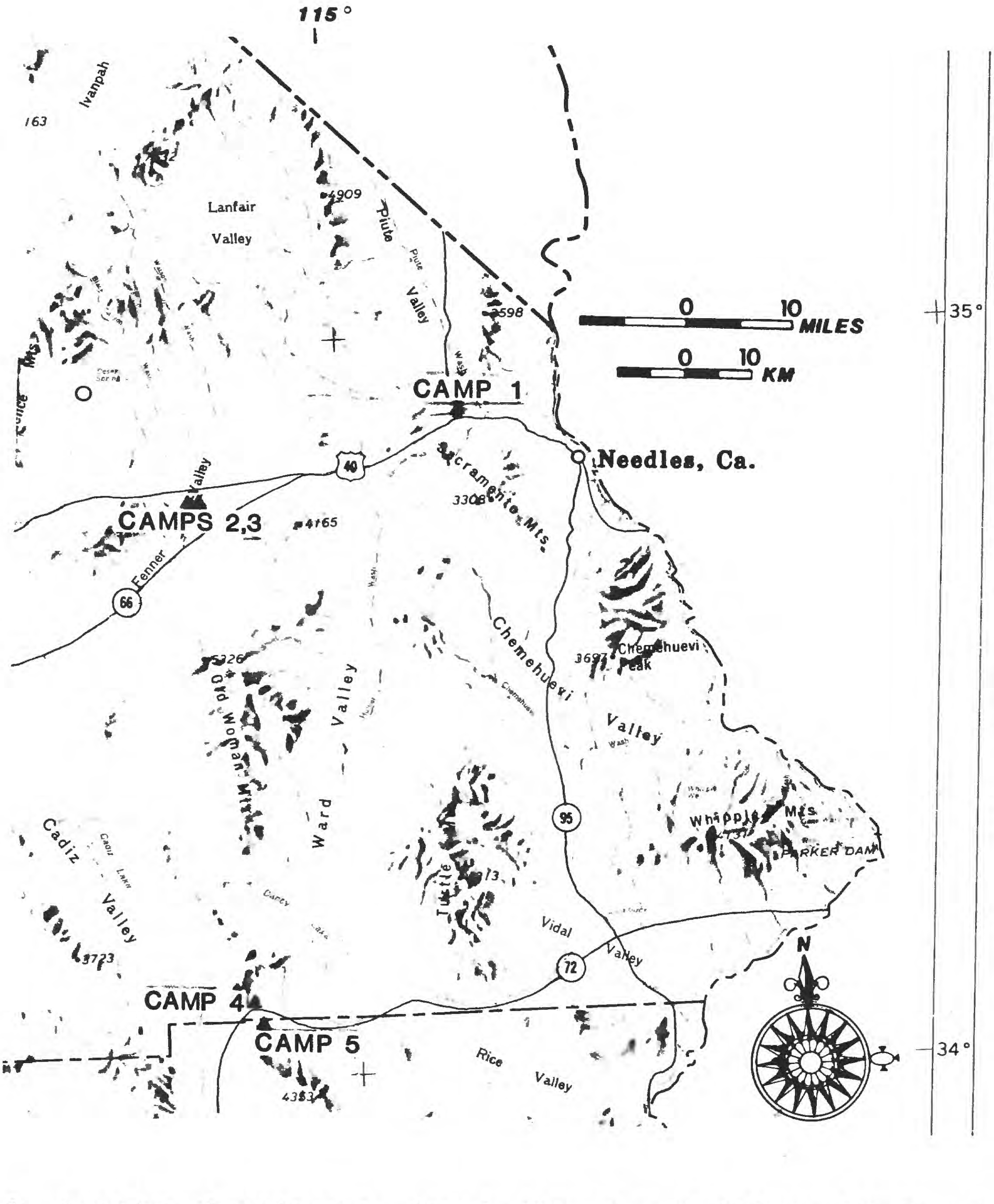


FIGURE 3. Location of study area. Camp 1- Ibis; Camp 2- Clipper old; Camp 3- Clipper new; Camp 4- Iron Mountain; Camp 5- Granite.

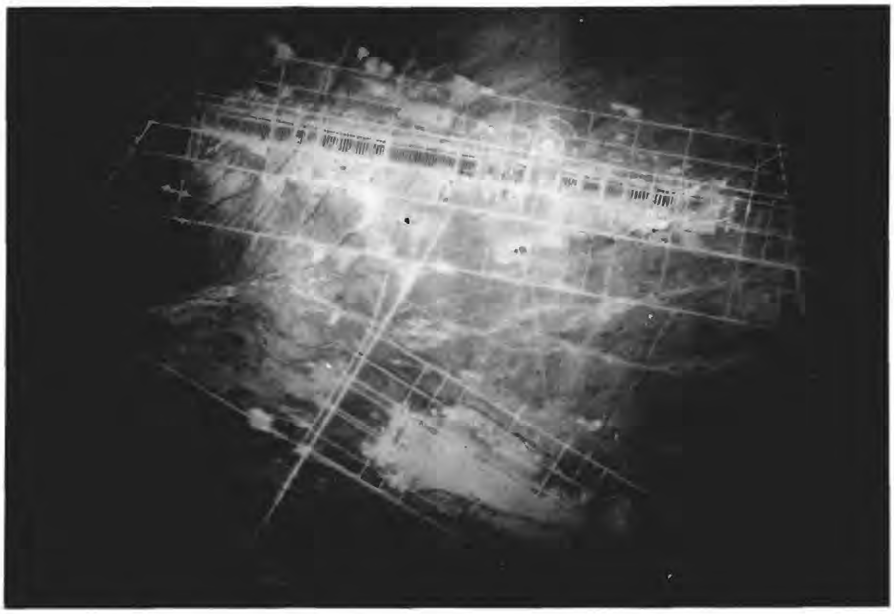


FIGURE 4. Contemporary aerial photo of new (upper camp) and old (lower camp, partial view) Camp Clipper.

FIGURE 5. Contemporary photo of main camp road at Camp Iron Mountain.

FIGURE 6. Recent photo of road at Camp Ibis. The predominant shrub is Ambrosia dumosa.

FIGURE 7. Contemporary photo of vehicle parking lot.

FIGURE 8. Recent photo of parking lot (foreground) at Camp Ibis. The predominant shrubs are Encelia frutescens and Ambrosia dumosa in contrast to the Larrea tridentata of the control in the background.

FIGURE 9. Contemporary photo of tent sites and adjacent tent road.

FIGURE 10. Recent photo of tent site (left portion of photo) and tent road (right) at Camp Ibis. The predominant shrub is Ambrosia dumosa.

FIGURE 11. Control plot at Camp Ibis. The predominant shrub is Larrea tridentata.

FIGURE 12. Metzger value explanation and example.

The Metzger value incorporates the three parameters of information that are collected with the recording penetrometer. These parameters are:

A Mean resistance value (measured in bars- 1 bar= 14.7 pounds per square inch) at a given depth of penetration. We chose to record mean resistance values in the soil profile at the 5, 10, 15, 20, 25, and 30 cm depths in each study plot. The resistance value at each of these depths is given a Metzger sub-value according to the rating scale in Figure 12a. Six ratings, with a maximum Metzger sub-value of 60, are possible for this parameter in a given study plot.

B Percentage of measurements recorded at given depth of penetration. In a given study plot, the recording penetrometer rarely penetrates to the same depth on every attempt. We recorded the number of penetrations, expressed as a % of the total number of attempts, for the 5, 10, 15, 20, 25, and 30 depths. For each depth, the % of penetrations is given a Metzger sub-value according to the rating scale in Figure 12a. Six ratings, with a maximum Metzger sub-value of 60, are possible for this parameter in a given study plot.

C Number of depths reached in given study plot. As stated above, we recorded resistance values at a maximum of 6 depths. In a given study plot, if at least 2 penetrations out of the total number of attempts were achieved at any of these 6 depths, then a Metzger sub-value of 1 was tallied according to the rating scale in Figure 12a. A total Metzger sub-value of 6 is possible for this parameter.

The Metzger sub-values are tallied to give a single Metzger value for a

FIGURE 12. Metzger value explanation and example, continued.

given study plot. This system is designed so that loose, uncompacted soils will have higher Metzger values than compacted soils where penetrometer resistance is greater at a given depth and the depth of penetration is more restricted.

** Metzger value rating scales and example appear on following page.

FIGURE 12a. rating scale for converting recording penetrometer results into METZGER VALUES

A mean resistance value (bars)

at given depth of penetration:	rating
0-4 bars	10
5-9	9
10-14	8
15-19	7
20-24	6
25-29	5
30-34	4
35-39	3
40-44	2
45-50	1

B % of measurements recorded

at given depth of penetration:	rating
90-100	10
80-89	9
70-79	8
60-69	7
50-59	6
40-49	5
30-39	4
20-29	3
10-19	2
0-9	1

C # of depths reached in

given study plot:	rating
6	6
5	5
4	4
3	3
2	2
1	1
0	0

Example: 200 reedings taken in a study plot yield the following results:

A The following mean values were recorded at each given depth:

	Metzger rating
5 cm - 12 bars	8
10 cm - 18	7
15 cm - 23	6
20 cm - 25	5
25 cm - 31	4
total:	30

B The % of measurements penetrating to each depth yields the following Metzger ratings:

	Metzger rating
5 cm - 99%	10
10 cm - 86	9
15 cm - 72	8
20 cm - 61	7
25 cm - 53	6
total:	40

C 5 depths were reached in the plot; No readings were recorded at 30 cm. Metzger rating is 5.

* Totals of A, B, and C are added to give a Metzger value of 75 for this study plot.

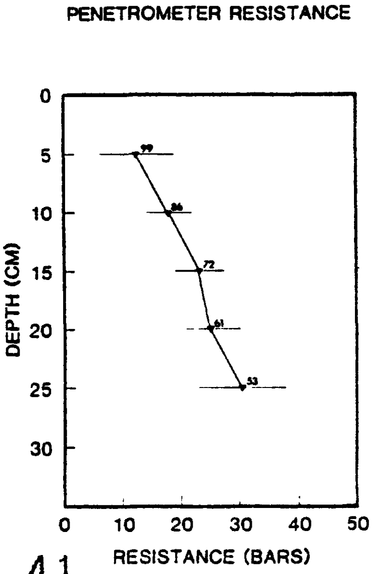


FIGURE 13.
CAMP IBIS

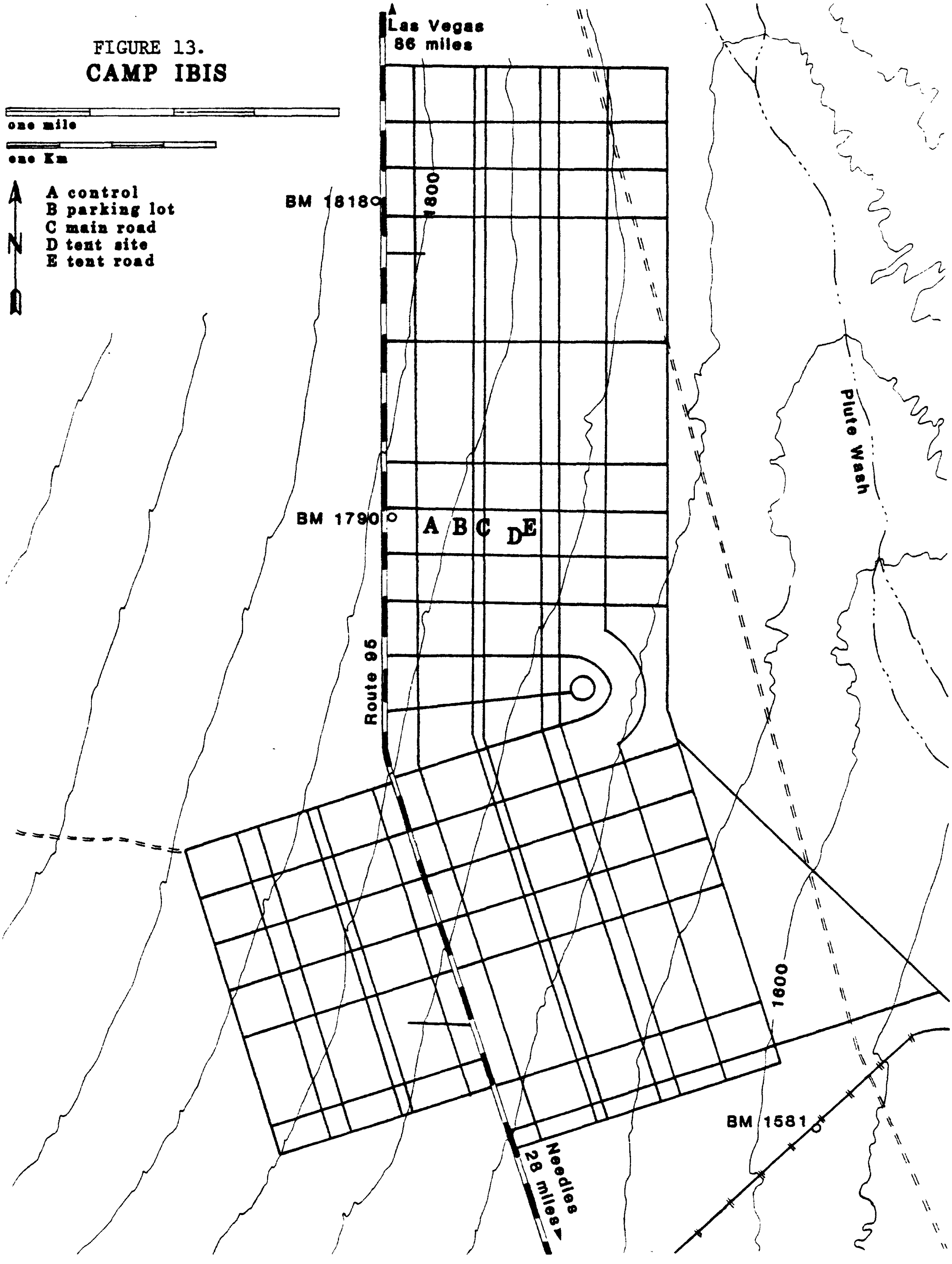
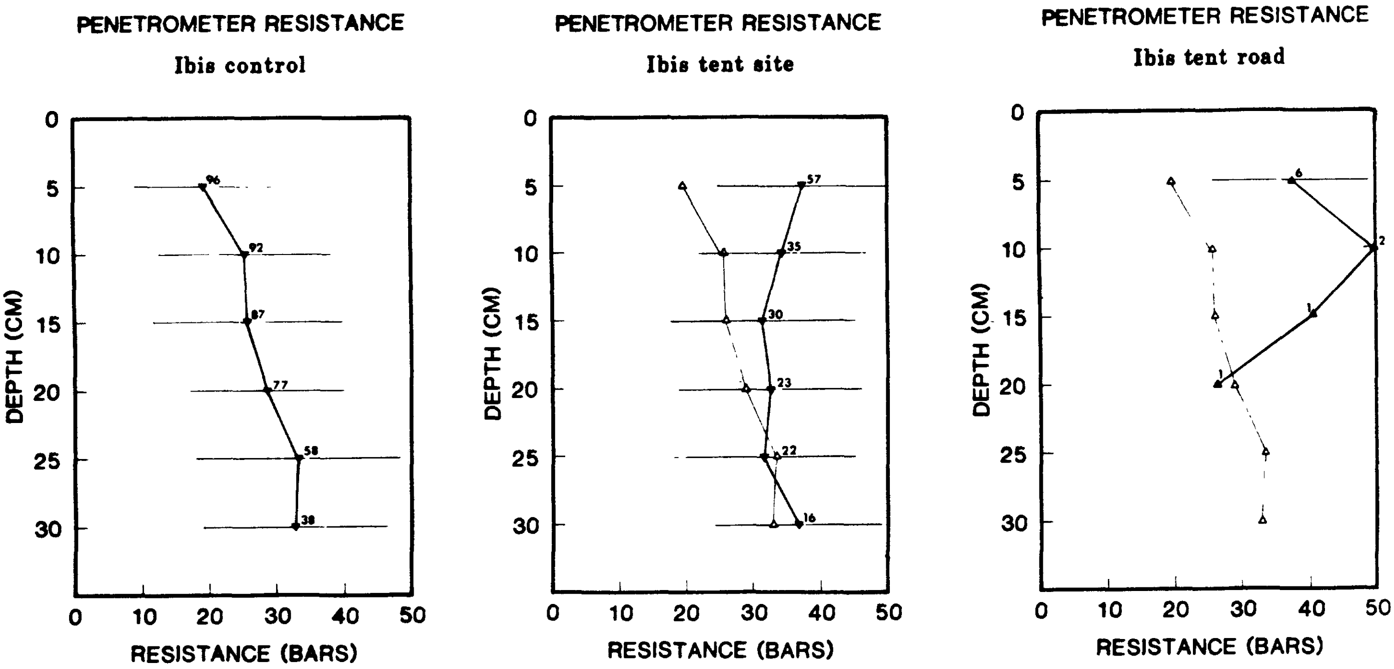
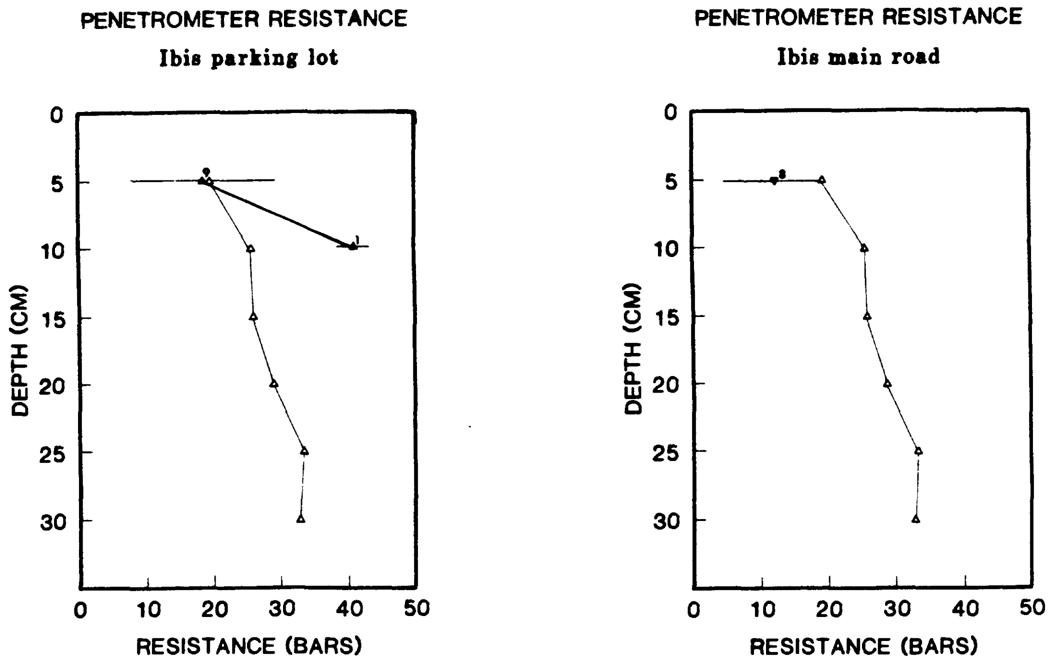


FIGURE 14. Establishment of vegetation in disturbed areas on a previously unvegetated surface (right half of photo).

FIGURE 15.





LEGEND FOR FIGURES 15, 19, 22, 25, and 29.

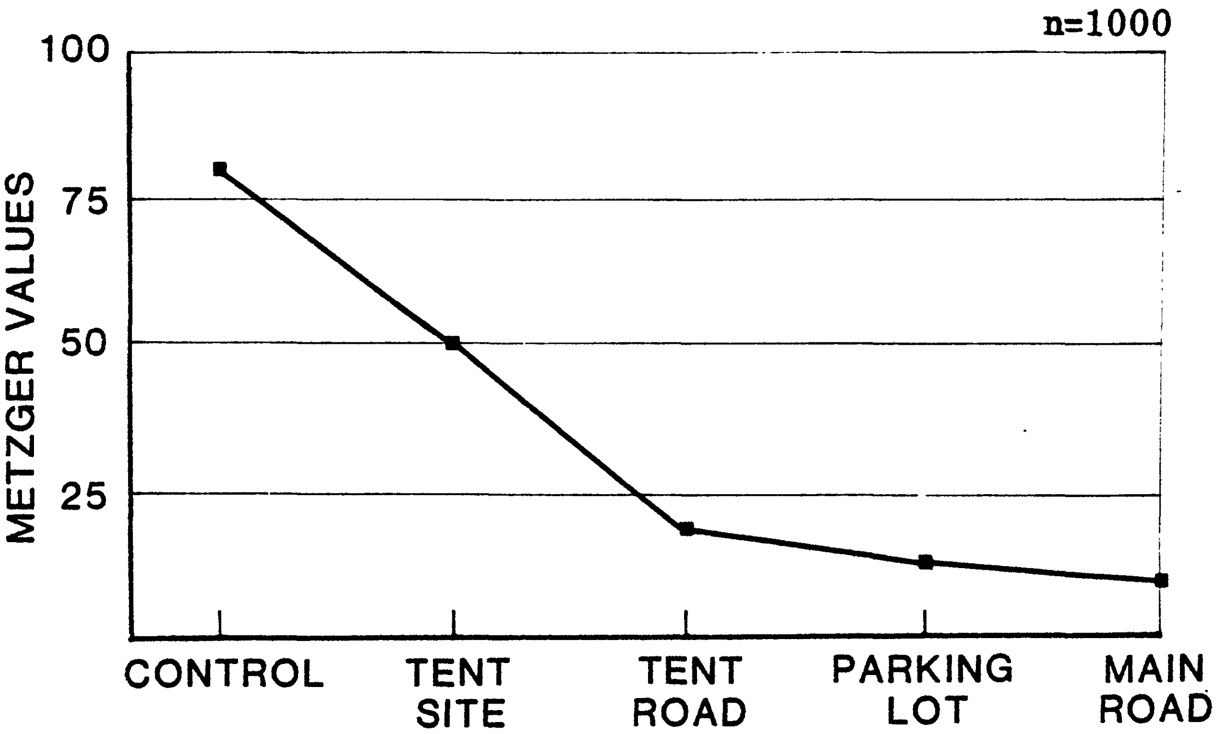
▼ -mean resistance value recorded at corresponding depth.

△ -indicates resistance values of control.

-bar extending horizontally from means is standard deviation.

-numbers within graphs, adjacent to means, are percent of measurements penetrating to corresponding depth (200 attempts in each study plot).

FIGURE 16. **METZGER VALUES**
Camp Ibis



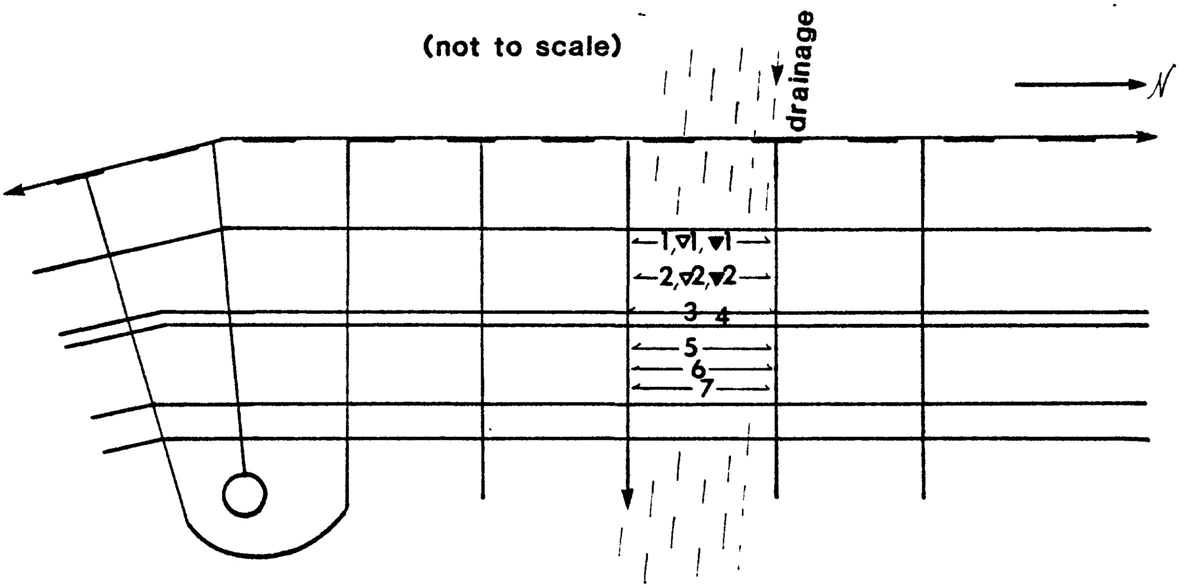
METZGER VALUES for all five camps

LOCATION	control	tent site	tent road	parking lot	main road
Ibis	79	50	19	13	10
old Clipper	83	71	55	58	15
new Clipper	99	68	41	39	17
Iron Mtn.	84	45	1	0	18
Granite	103	52	--	6	23
COMBINED (means)	90	57	29	23	17

FIGURE 17.

CHANNEL TRANSECTS

Camp Ibis



CATEGORY	TRANSECT #	CHANNEL DENSITY (avg.)	CHANNEL CHARACTERISTICS		
			minor	medium	major
control	1, ▽1, ▼1	8.6	1	6	1
tent area	5,6,7	14.5	1	8	4
parking lot	2, ▽2, ▼2	14.1	1	9	3
main road	3	13.0	0	7	4
road berm	4	7.0	0	3	3

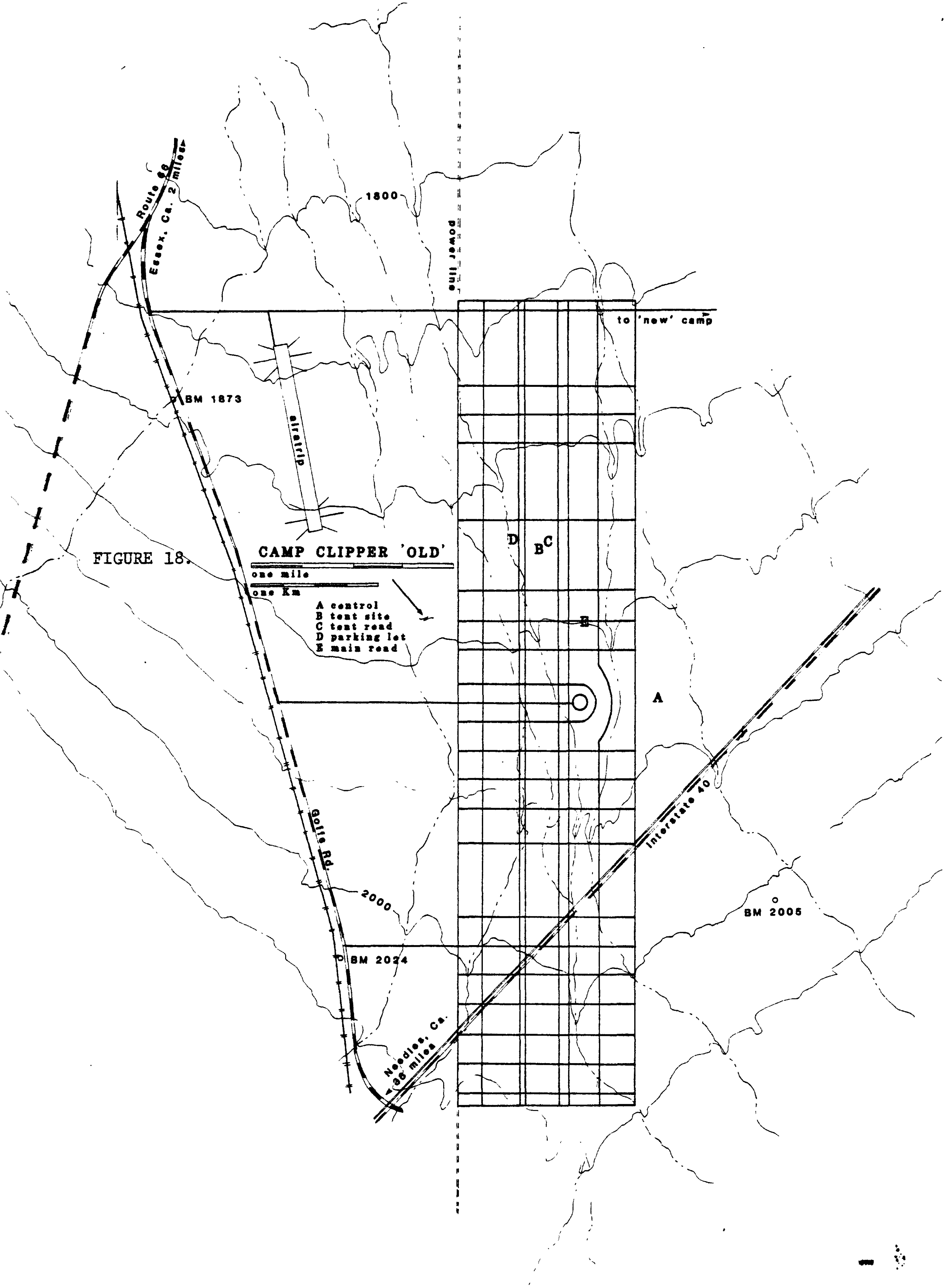
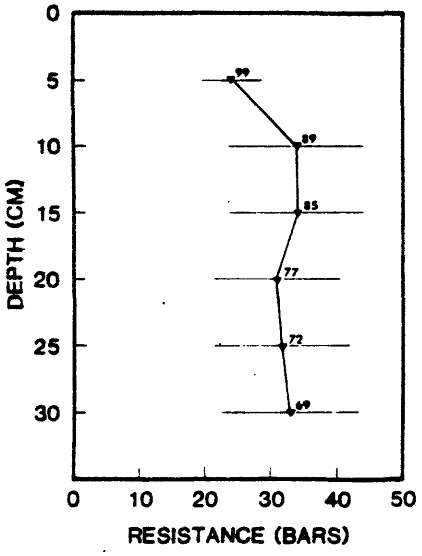

Route 66
Essex, Ca. 2 miles
1800
power line
to 'new' camp
BM 1873
airstrip
CAMP CLIPPER 'OLD'
one mile
one Km
A control
B tent site
C tent road
D parking lot
E main road
D
B
C
E
A
Goffs Rd.
2000
BM 2024
BM 2005
Interstate 40
Needles, Ca.
36 miles

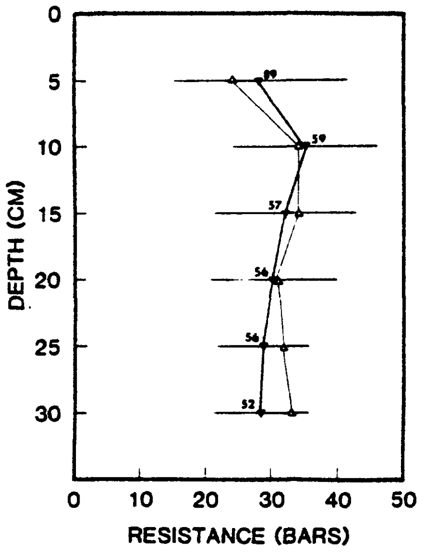
FIGURE 18.

FIGURE 19.

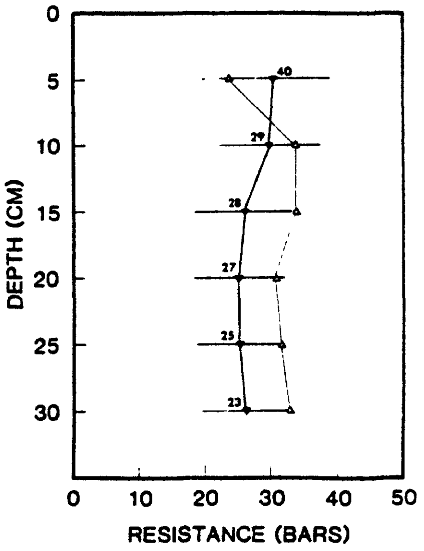
PENETROMETER RESISTANCE
old Clipper control



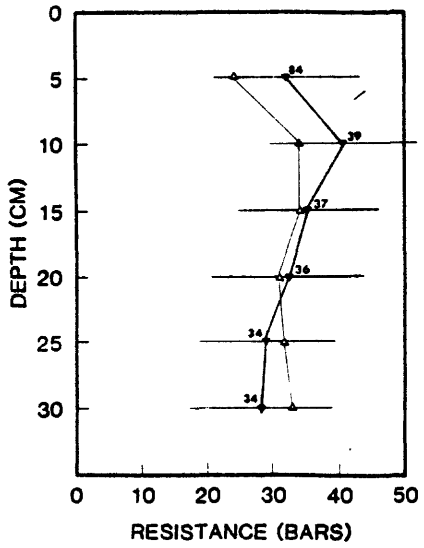
PENETROMETER RESISTANCE
old Clipper tent site



PENETROMETER RESISTANCE
old Clipper tent road



PENETROMETER RESISTANCE
old Clipper parking lot



PENETROMETER RESISTANCE
old Clipper main road

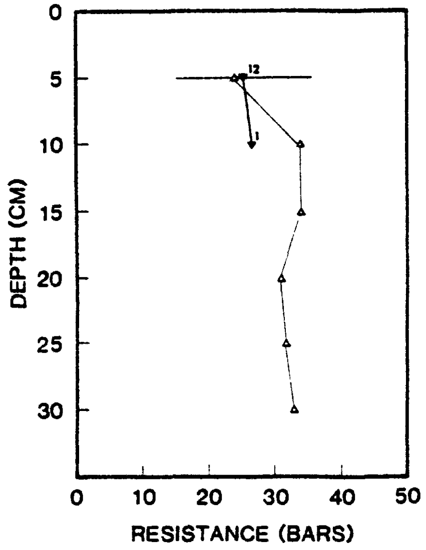
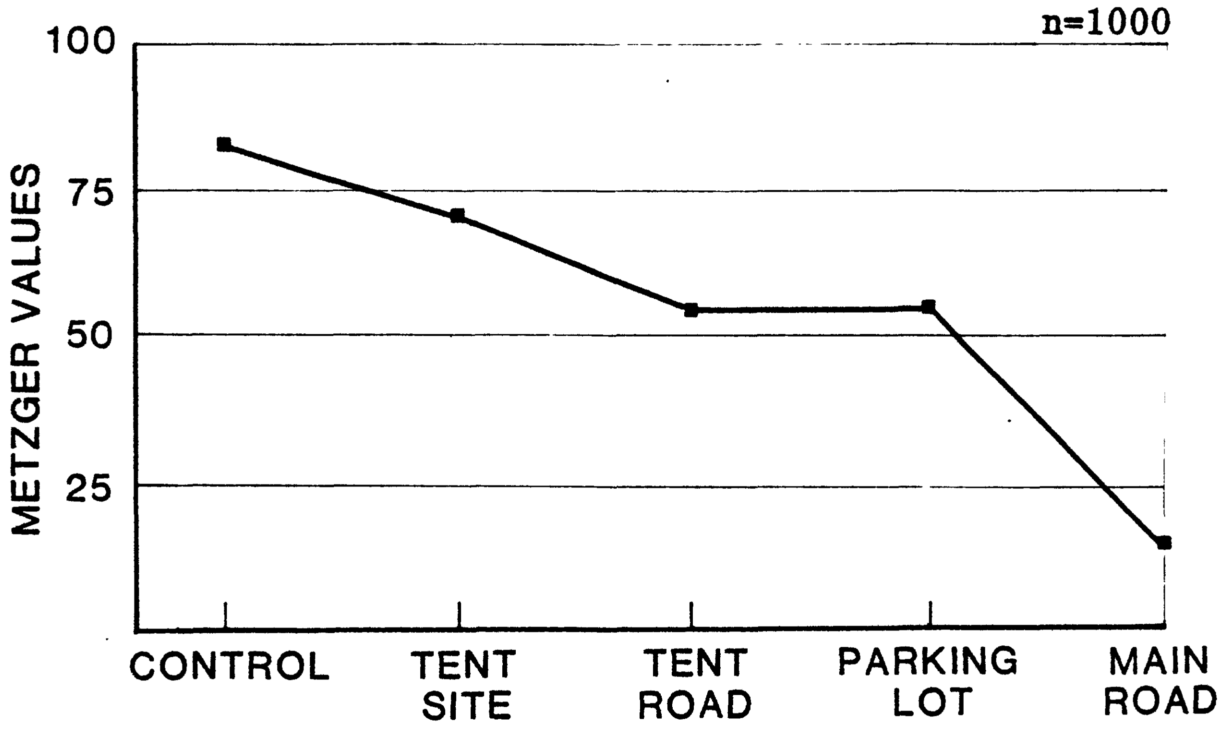


FIGURE 20.

METZGER VALUES
Camp Clipper old



METZGER VALUES for all five camps

LOCATION	control	tent site	tent road	parking lot	main road
Ibis	79	50	19	13	10
old Clipper	83	71	55	58	15
new Clipper	99	68	41	39	17
Iron Mtn.	84	45	1	0	18
Granite	103	52	--	6	23
COMBINED (means)	90	57	29	23	17

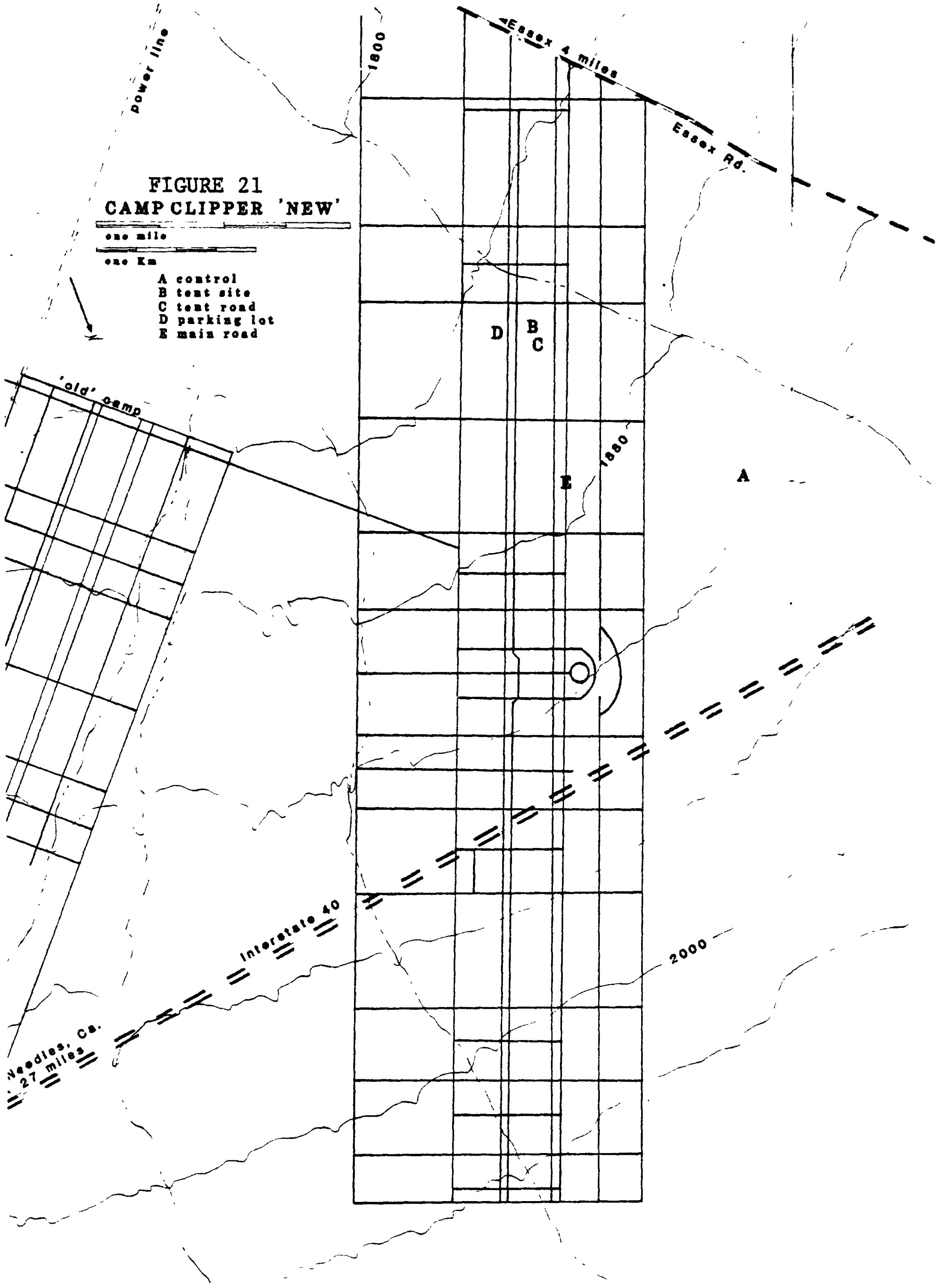


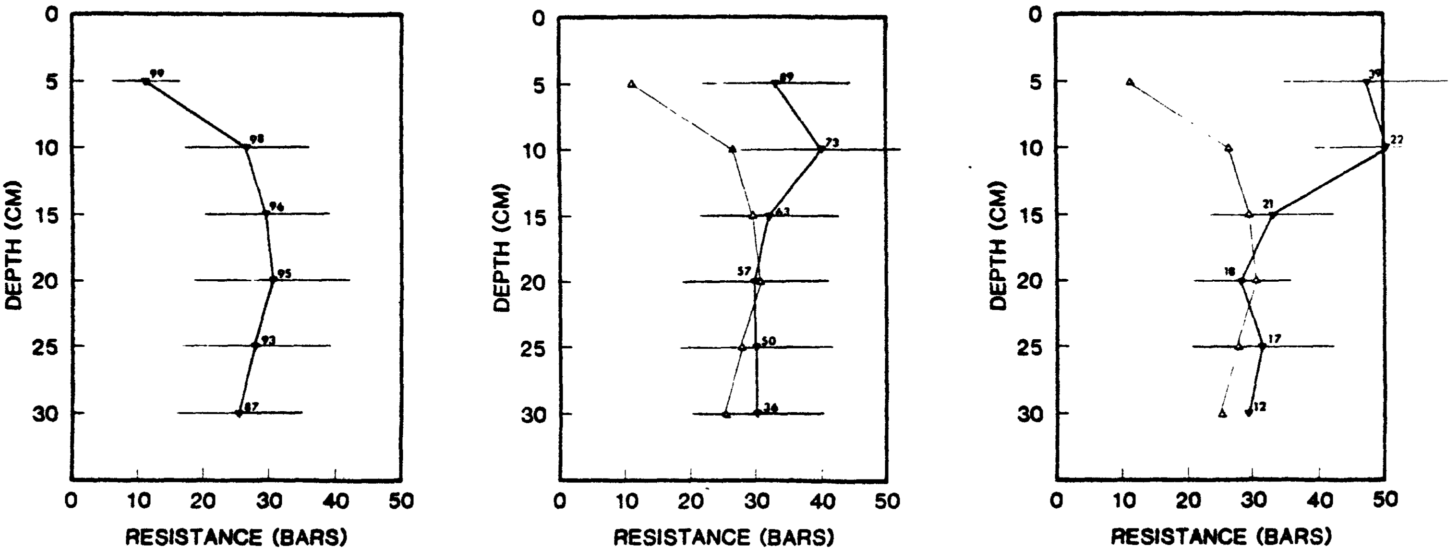
FIGURE 21
CAMP CLIPPER 'NEW'

FIGURE 22.

PENETROMETER RESISTANCE
new Clipper control

PENETROMETER RESISTANCE
new Clipper tent site

PENETROMETER RESISTANCE
new Clipper tent road



PENETROMETER RESISTANCE
new Clipper parking lot

PENETROMETER RESISTANCE
new Clipper main road

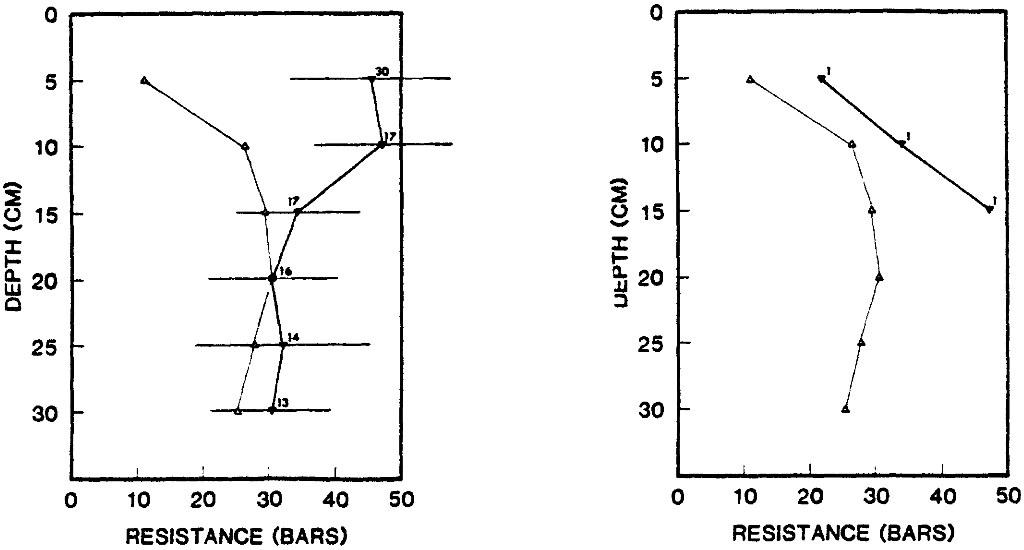
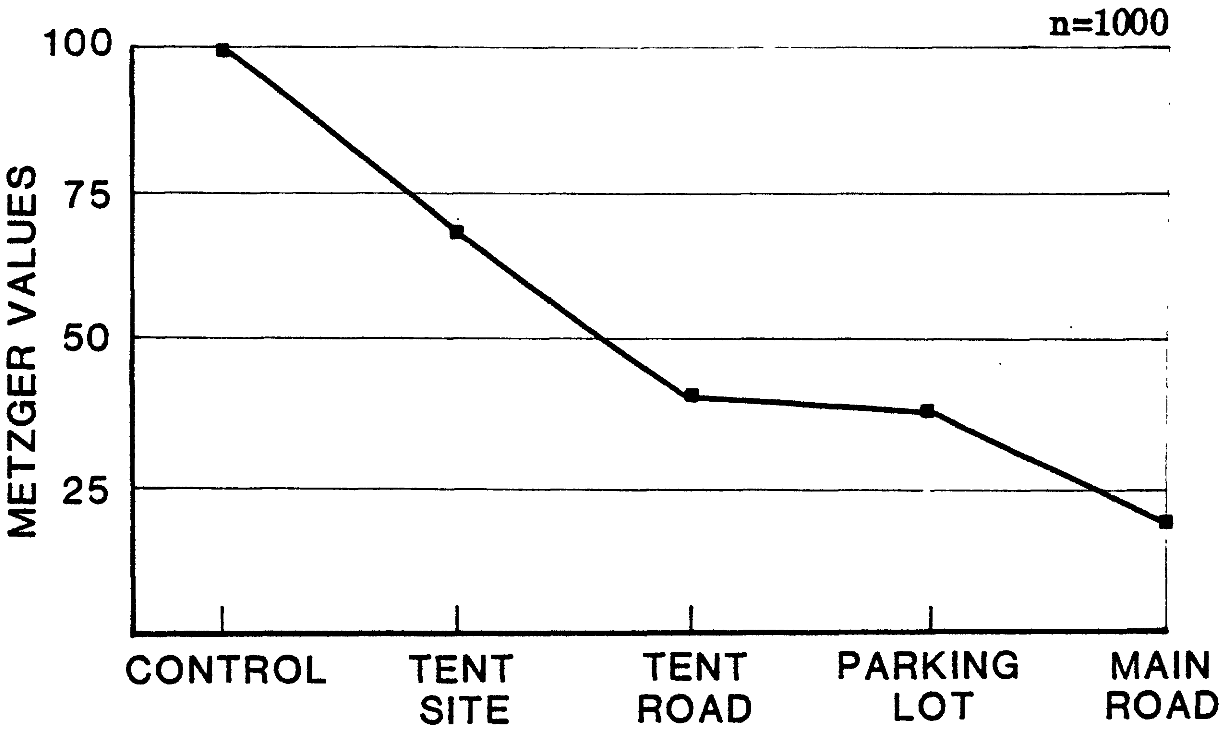


FIGURE 23.

METZGER VALUES
Camp Clipper new



METZGER VALUES for all five camps

LOCATION	control	tent site	tent road	parking lot	main road
Ibis	79	50	19	13	10
old Clipper	83	71	55	58	15
new Clipper	99	68	41	39	17
Iron Mtn.	84	45	1	0	18
Granite	103	52	--	6	23
COMBINED (means)	90	57	29	23	17

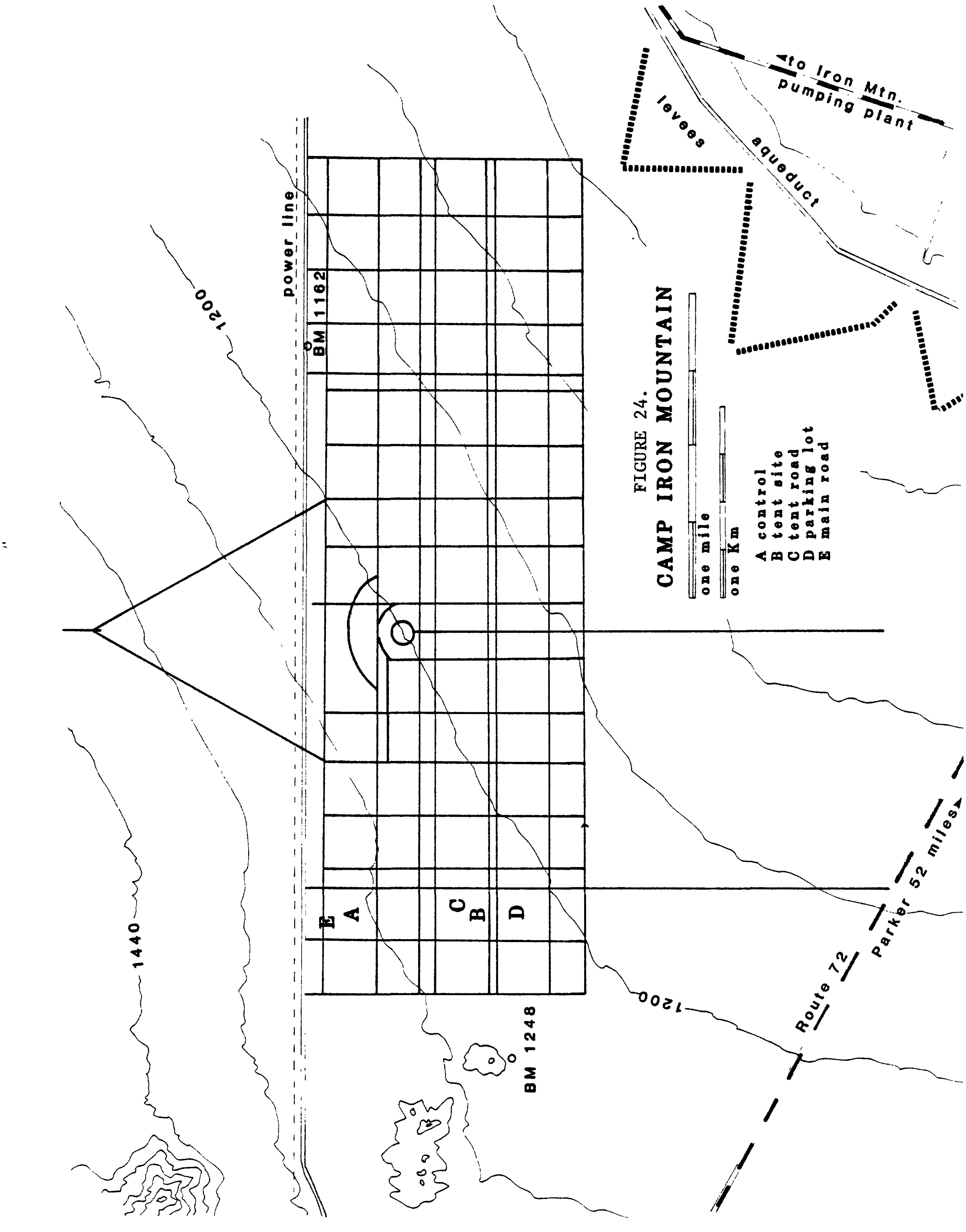


FIGURE 24.
CAMP IRON MOUNTAIN

A control
B tent site
C tent road
D parking lot
E main road

FIGURE 25.

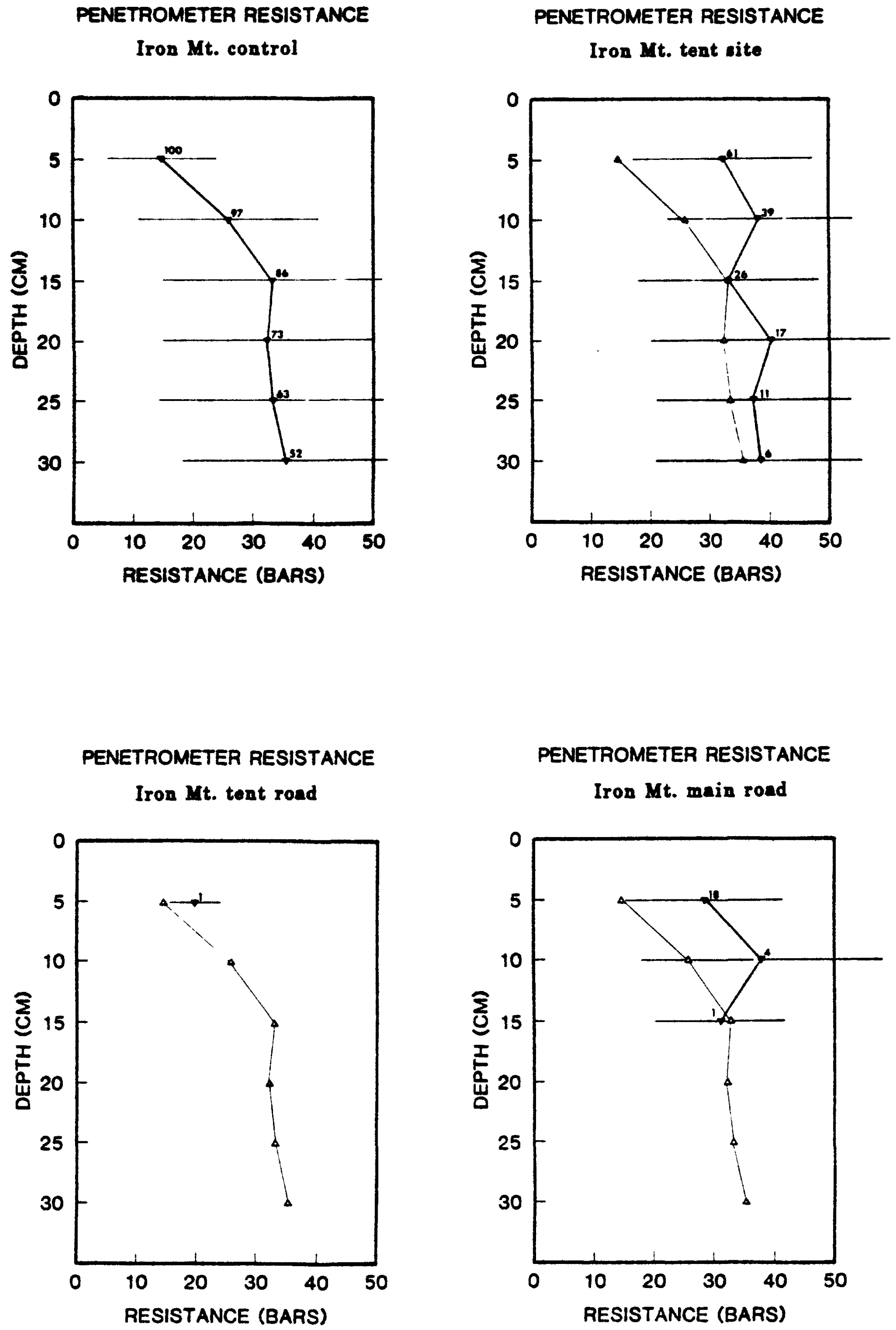
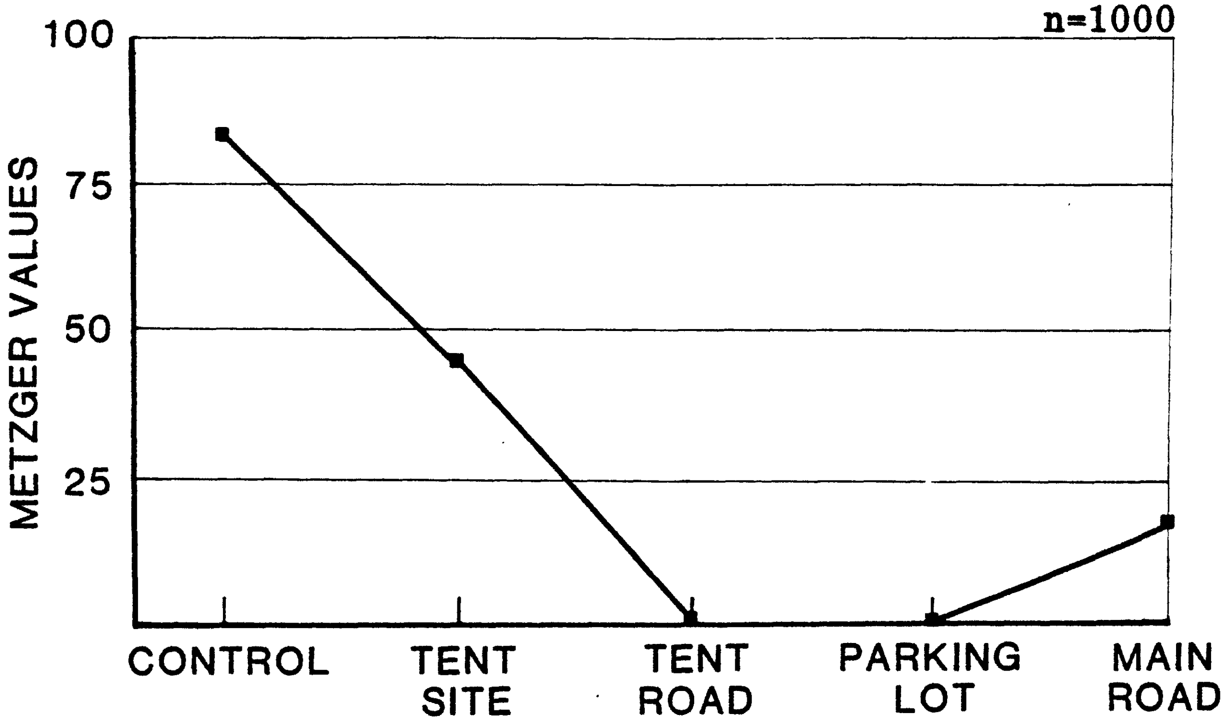

PENETROMETER RESISTANCE
Iron Mt. control
DEPTH (CM)
0
5
10
15
20
25
30
100
97
86
73
63
52
0
10
20
30
40
50
RESISTANCE (BARS)
PENETROMETER RESISTANCE
Iron Mt. tent site
DEPTH (CM)
0
5
10
15
20
25
30
61
39
26
17
11
6
0
10
20
30
40
50
RESISTANCE (BARS)
PENETROMETER RESISTANCE
Iron Mt. tent road
DEPTH (CM)
0
5
10
15
20
25
30
1
0
10
20
30
40
50
RESISTANCE (BARS)
PENETROMETER RESISTANCE
Iron Mt. main road
DEPTH (CM)
0
5
10
15
20
25
30
18
4
1
0
10
20
30
40
50
RESISTANCE (BARS)

FIGURE 26.

METZGER VALUES
Camp Iron Mountain



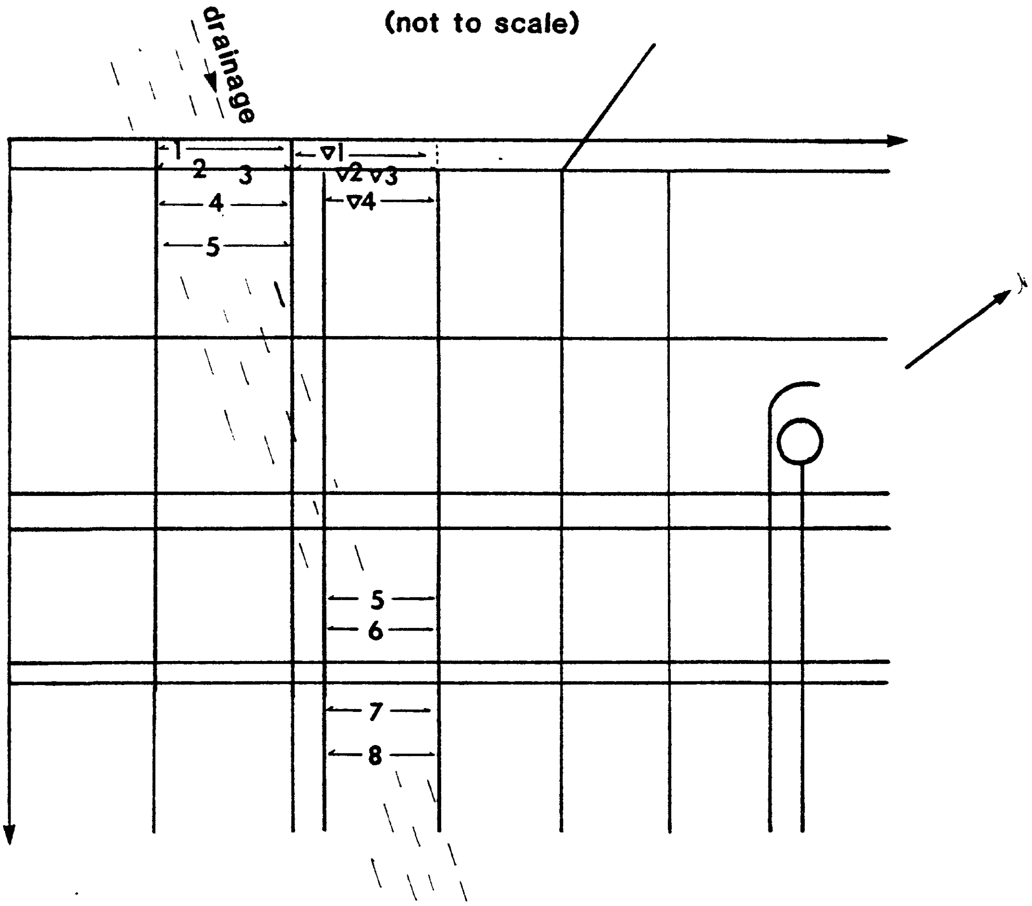
METZGER VALUES for all five camps

LOCATION	control	tent site	tent road	parking lot	main road
Ibis	79	50	19	13	10
old Clipper	83	71	55	58	15
new Clipper	99	68	41	39	17
Iron Mtn.	84	45	1	0	18
Granite	103	52	--	6	23
COMBINED (means)	90	57	29	23	17

FIGURE 27.

CHANNEL TRANSECTS

Camp Iron Mountain



CATEGORY	TRANSECT #	CHANNEL DENSITY (avg.)	CHANNEL CHARACTERISTICS minor	medium	major
control	1,4,5,▽1,▽4	11.1	16	13	8
tent area	5,6	10.9	5	5	11
parking lot	7,8	5.6	5	8	5
main road	2,▽2	6.2	5	5	11
road berm	3,▽3	1.5	--	1	6

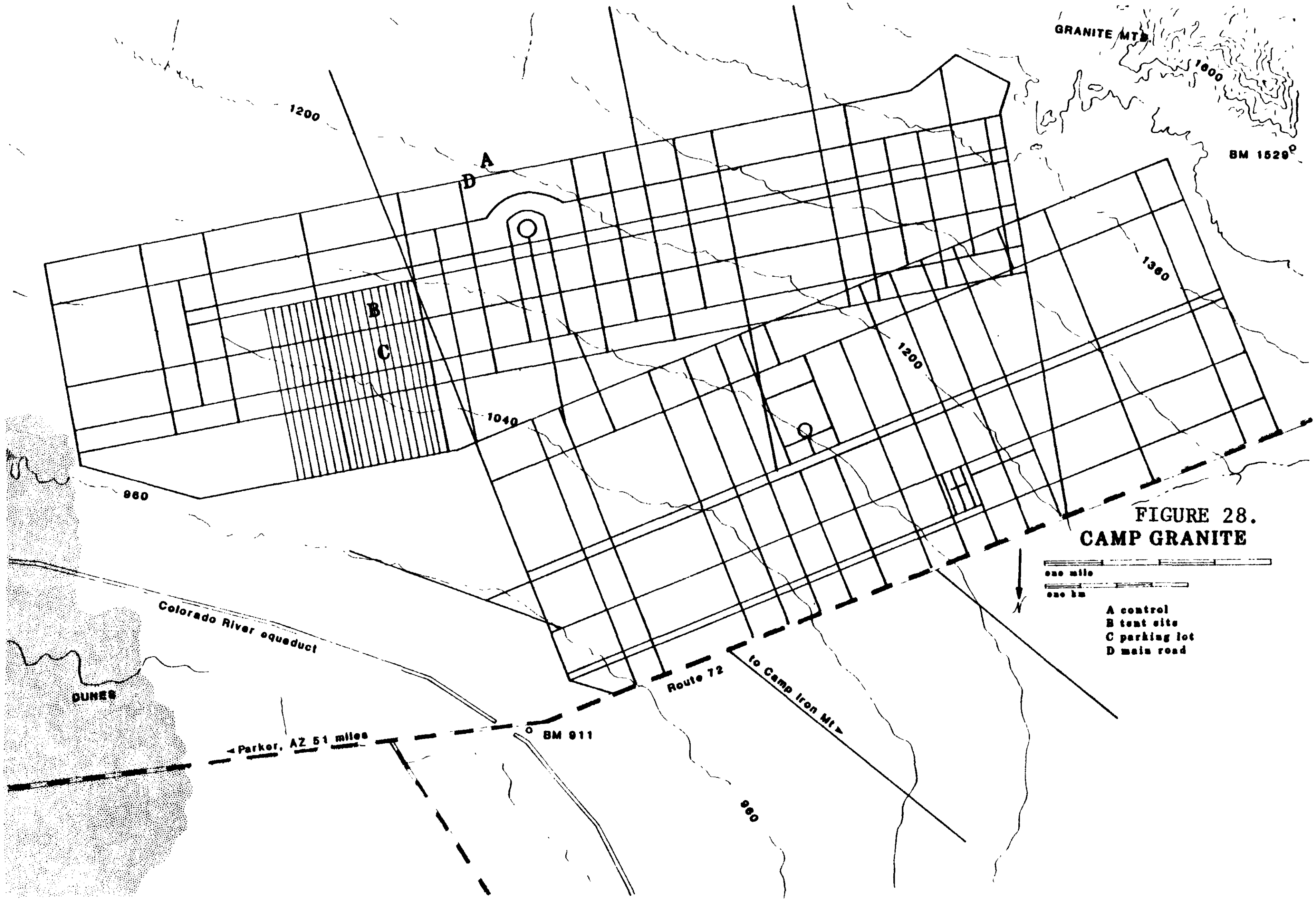
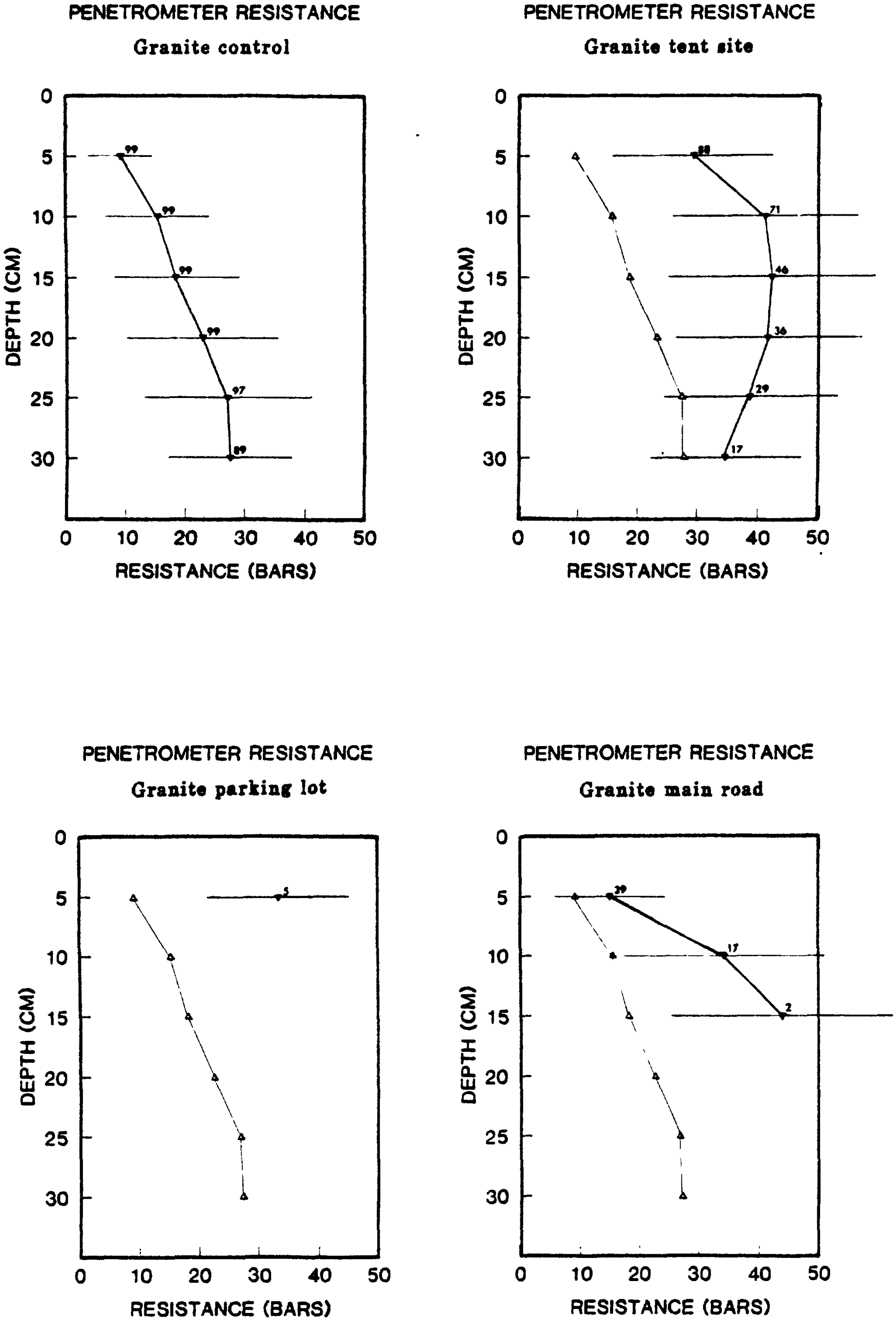


FIGURE 28.
CAMP GRANITE

FIGURE 29.



PENETROMETER RESISTANCE Granite control

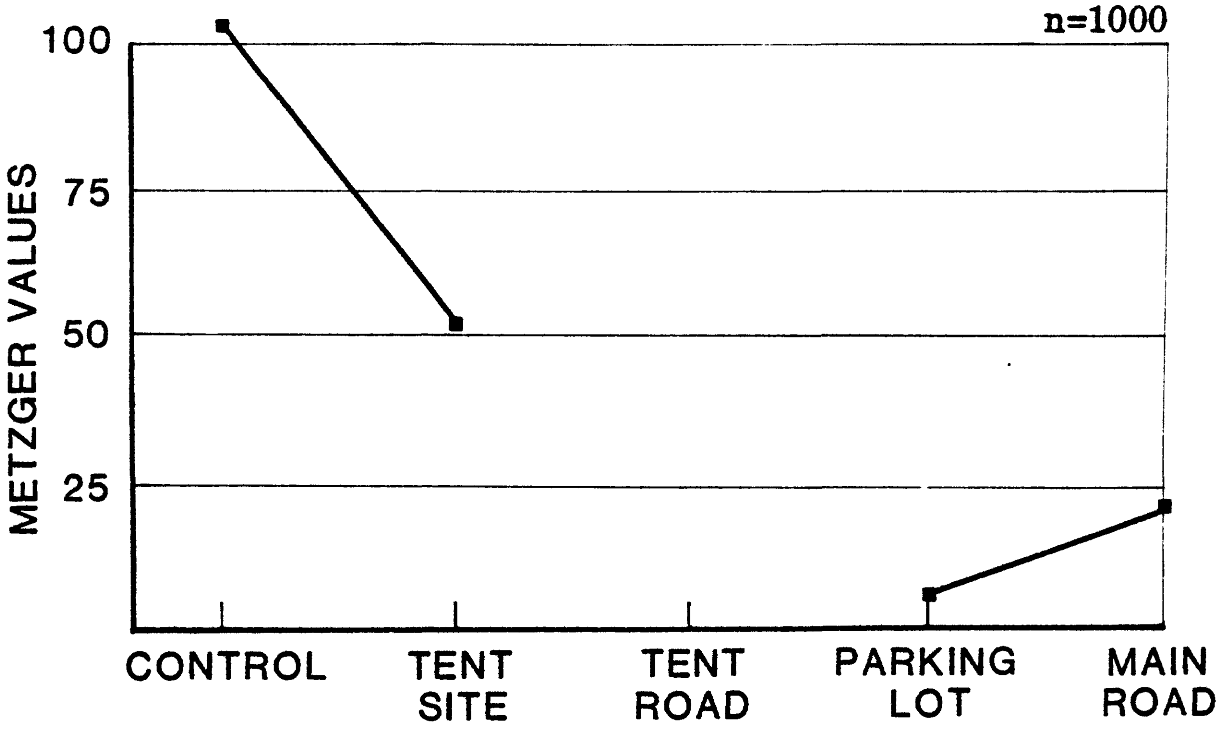
PENETROMETER RESISTANCE Granite tent site

PENETROMETER RESISTANCE Granite parking lot

PENETROMETER RESISTANCE Granite main road

FIGURE 30.

METZGER VALUES
Camp Granite



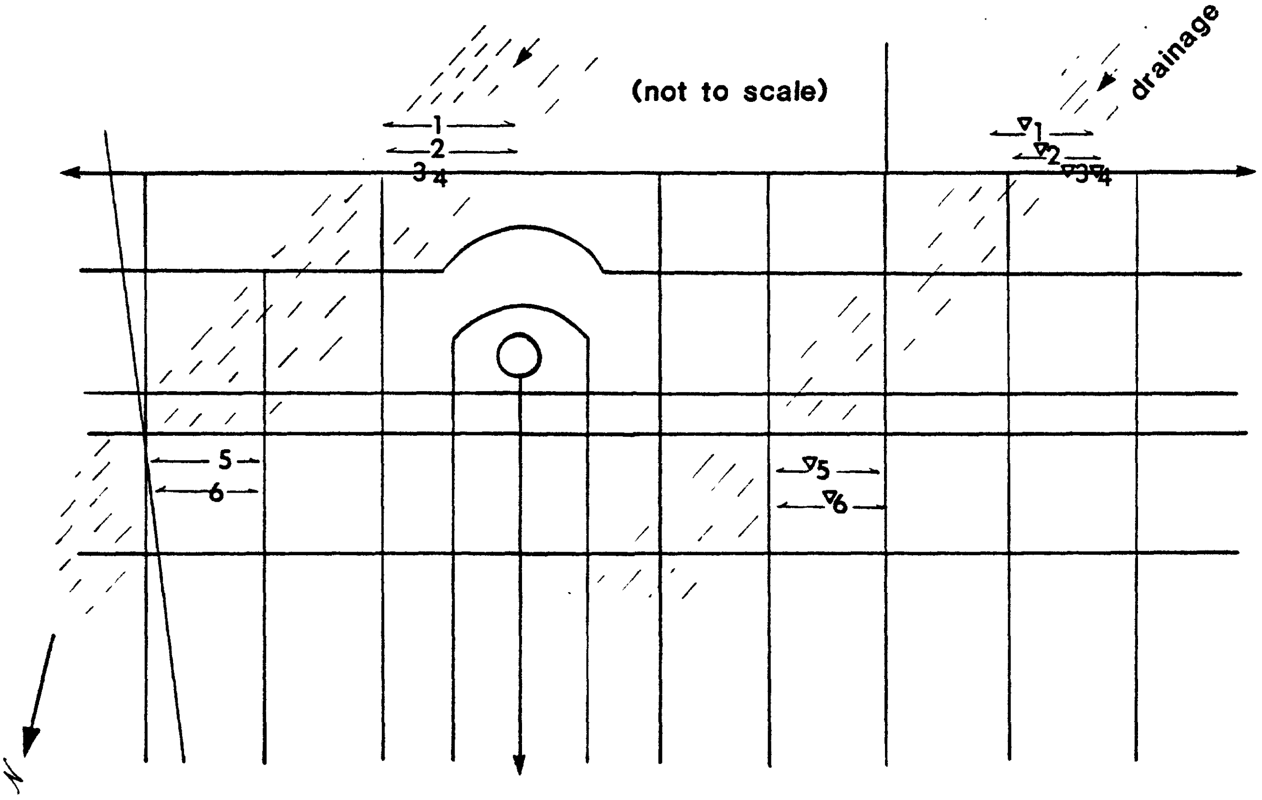
METZGER VALUES for all five camps

LOCATION	control	tent site	tent road	parking lot	main road
Ibis	79	50	19	13	10
old Clipper	83	71	55	58	15
new Clipper	99	68	41	39	17
Iron Mtn.	84	45	1	0	18
Granite	103	52	--	6	23
COMBINED (means)	90	57	29	23	17

FIGURE 31.

CHANNEL TRANSECTS

Camp Granite



CATEGORY	TRANSECT #	CHANNEL DENSITY (avg.)	CHANNEL CHARACTERISTICS minor	medium	major
control	1, 2, ▽1, ▽2	8.8	4	8	12
tent area	5, 6, ▽5, ▽6	9.4	6	10	11
parking lot	--	--	--	--	--
main road	3, ▽3	3.3	2	2	5
road berm	4, ▽4	1.7		all major (5)	

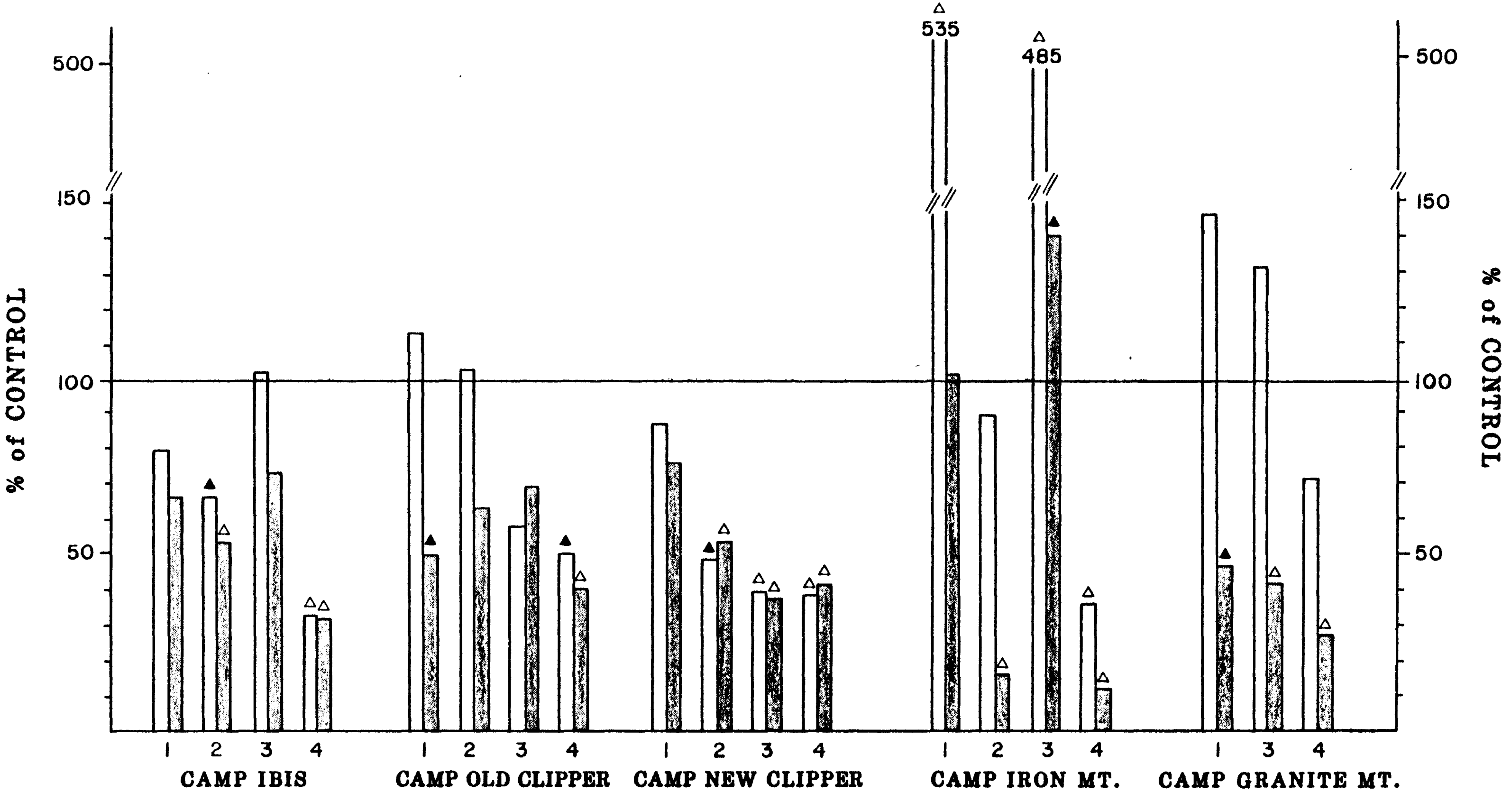


Figure 32. Density and cover of perennial shrubs, represented as percentage of the control, in disturbed areas at five abandoned WW II military camps.

1=tent sites, 2=tent roads, 3=parking lot, 4=main roads.

☐ = density

▨ = cover

△ = significant at $P < 0.01$

▲ = significant at $P < 0.05$

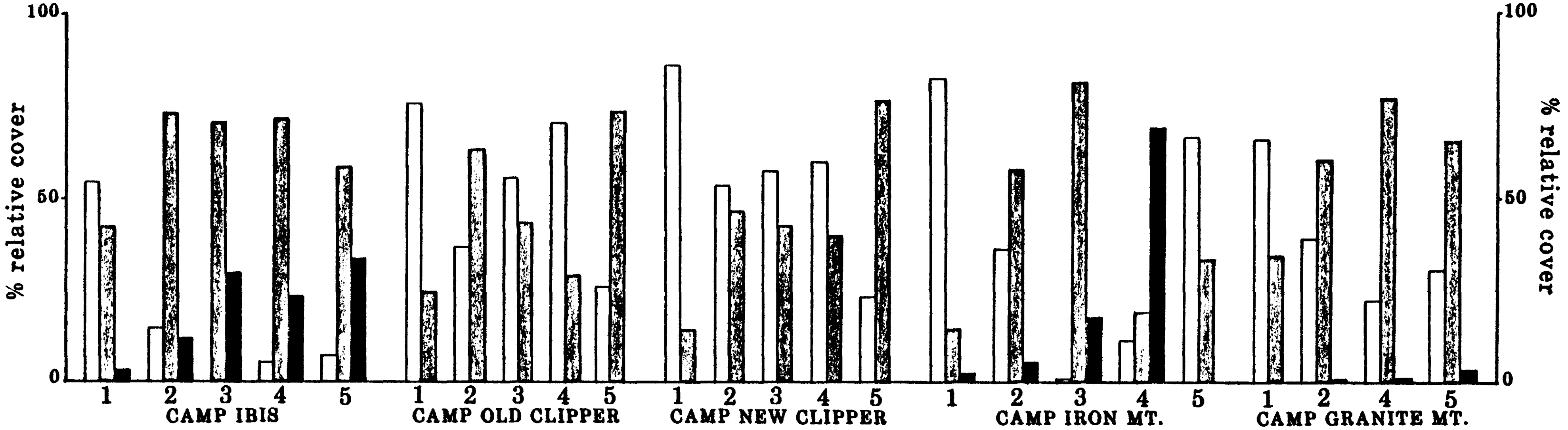
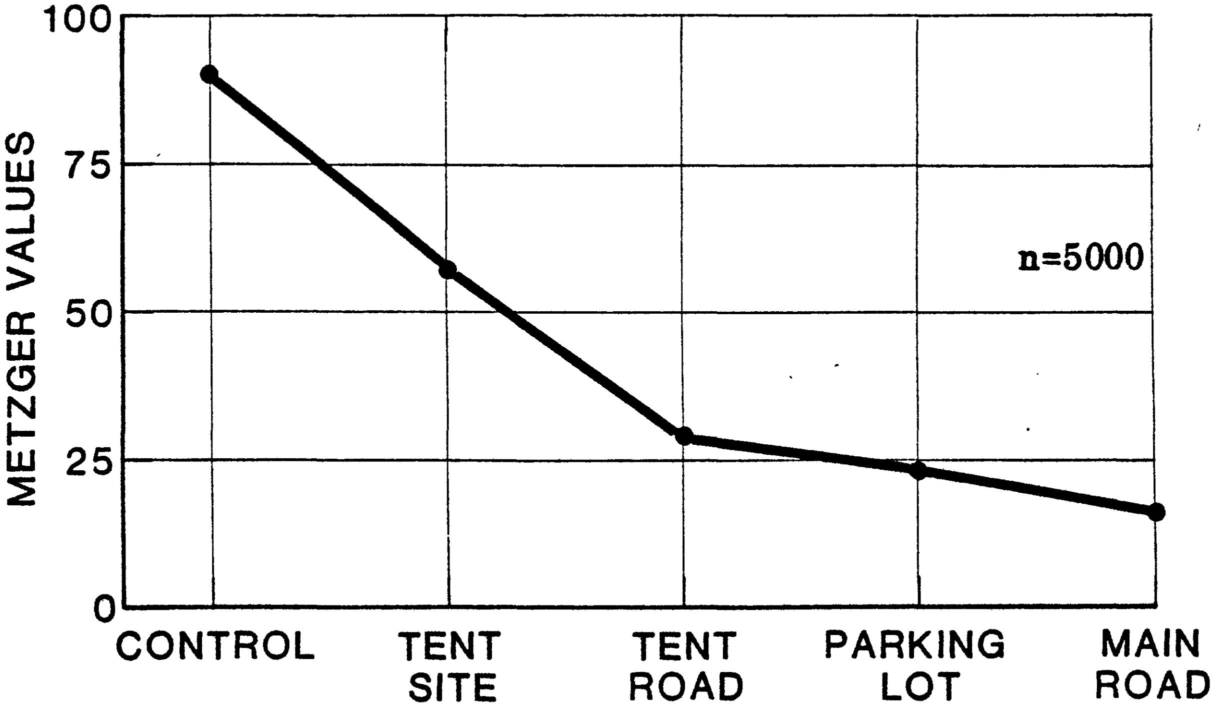


Figure 33 Comparison of the percentage of total cover (% relative cover) provided by long-lived (LL), long-lived opportunistic (LL OPP), and short-lived (SL) perennial shrubs among controls and disturbed areas in abandoned WW II military camps.

1=controls, 2=tent sites, 3=tent roads, 4=parking lots, 5=main roads; ☐=LL, ▨=LL OPP, ■=SL.

FIGURE 34.

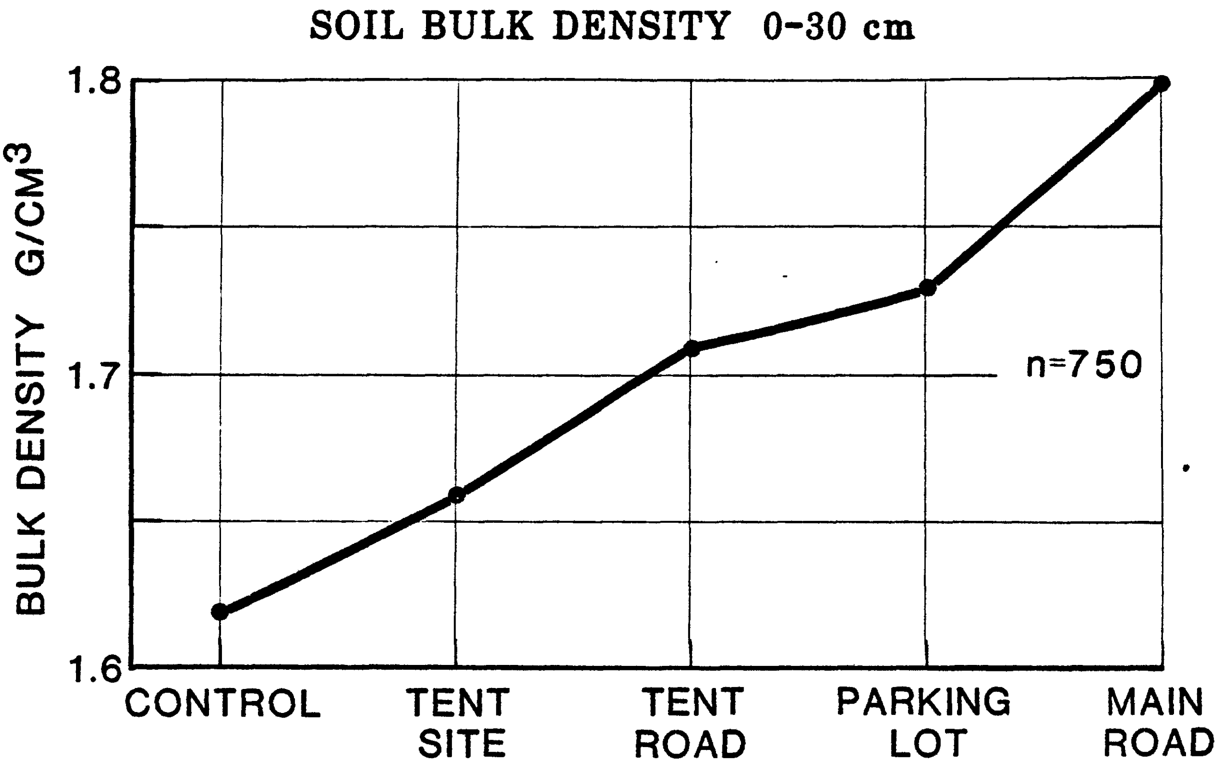
METZGER VALUES
all camps combined



METZGER VALUES for all five camps

LOCATION	control	tent site	tent road	parking lot	main road
Ibis	79	50	19	13	10
old Clipper	83	71	55	58	15
new Clipper	99	68	41	39	17
Iron Mtn.	84	45	1	0	18
Granite	103	52	--	6	23
COMBINED (means)	90	57	29	23	17

FIGURE 35.



Mean soil bulk density values for all camps combined.

FIGURE 36.

SOIL PARTICLE-SIZE DISTRIBUTION
CAMP IBIS

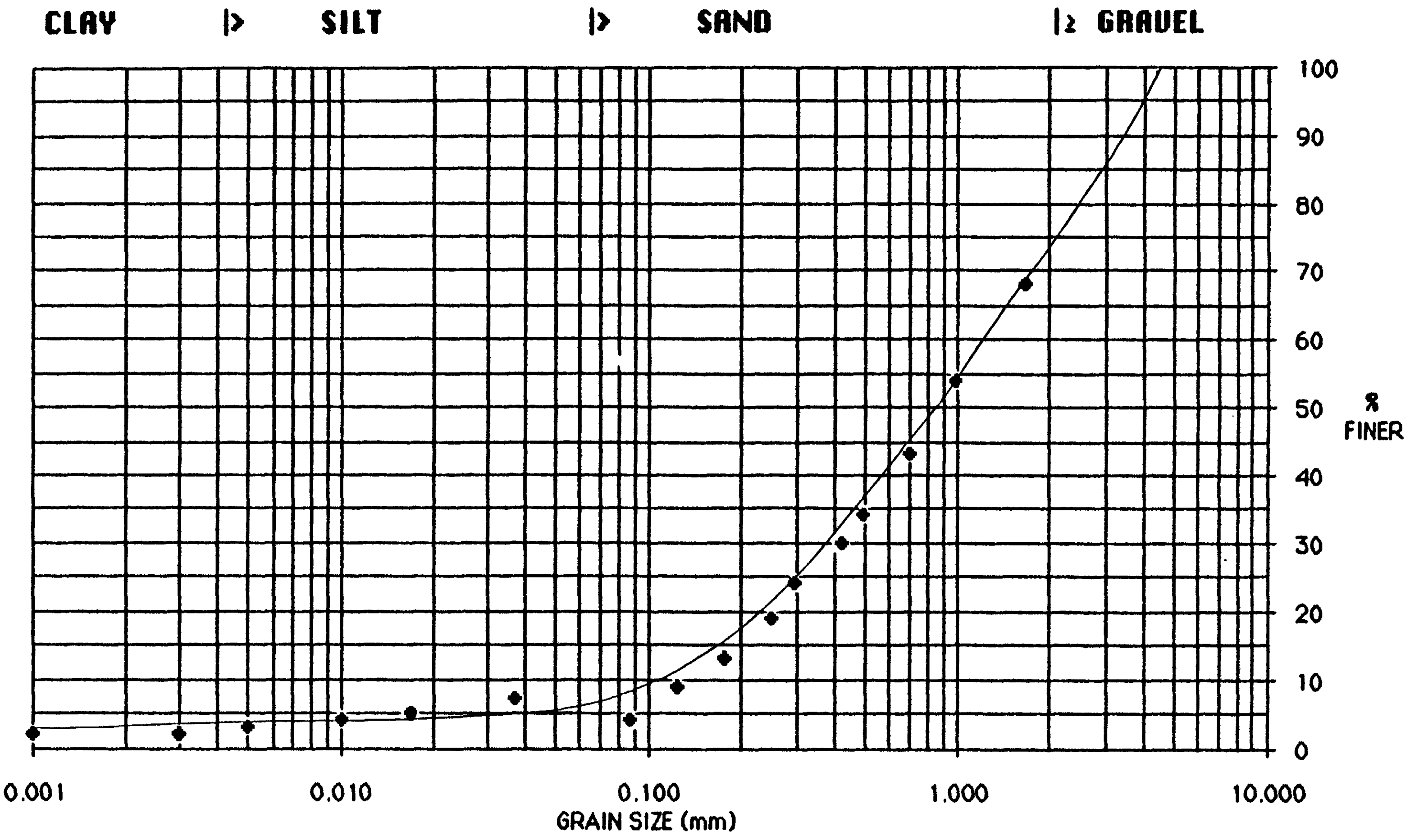


FIGURE 37.

SOIL PARTICLE-SIZE DISTRIBUTION
CAMP OLD CLIPPER

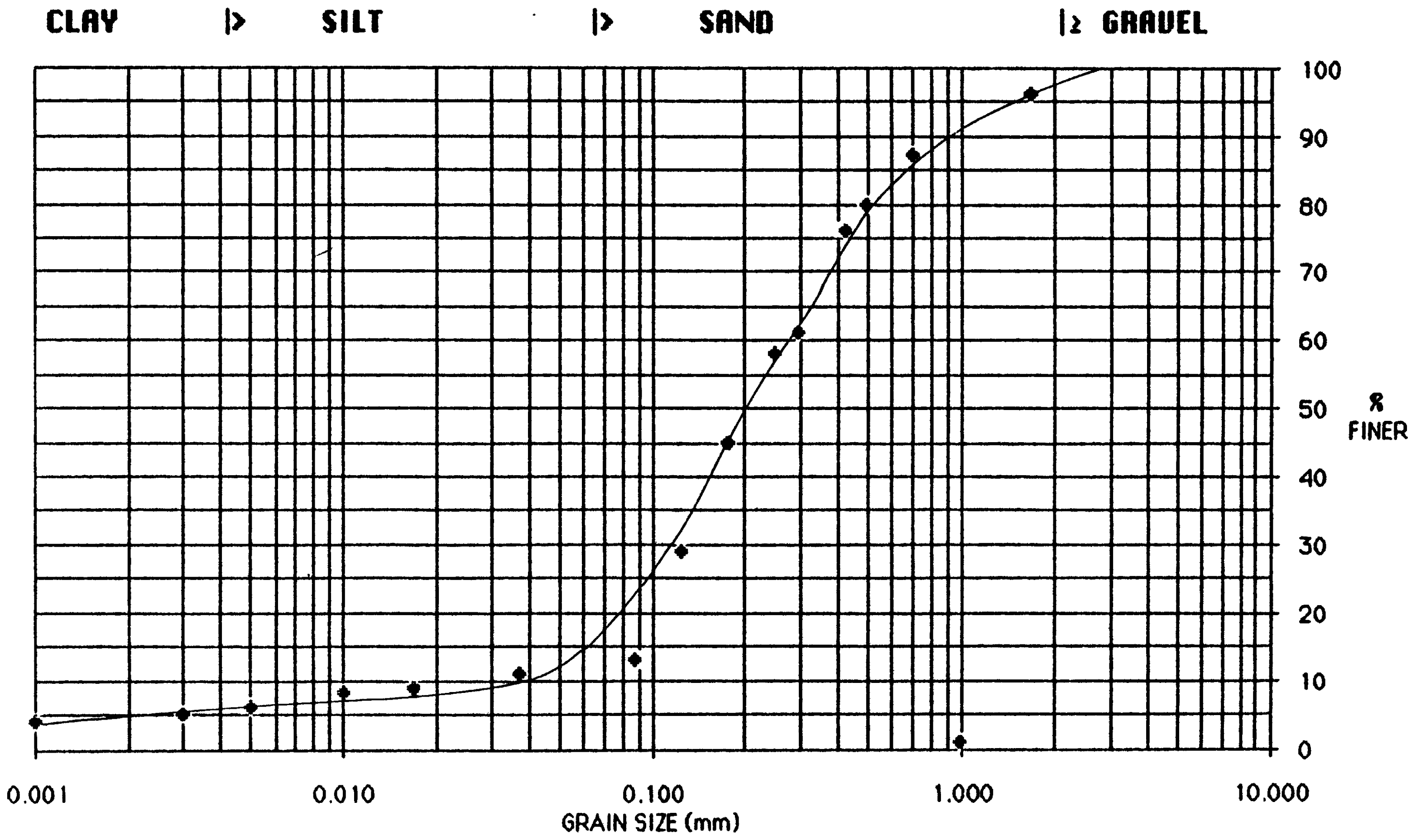


FIGURE 38.

SOIL PARTICLE-SIZE DISTRIBUTION
CAMP NEW CLIPPER

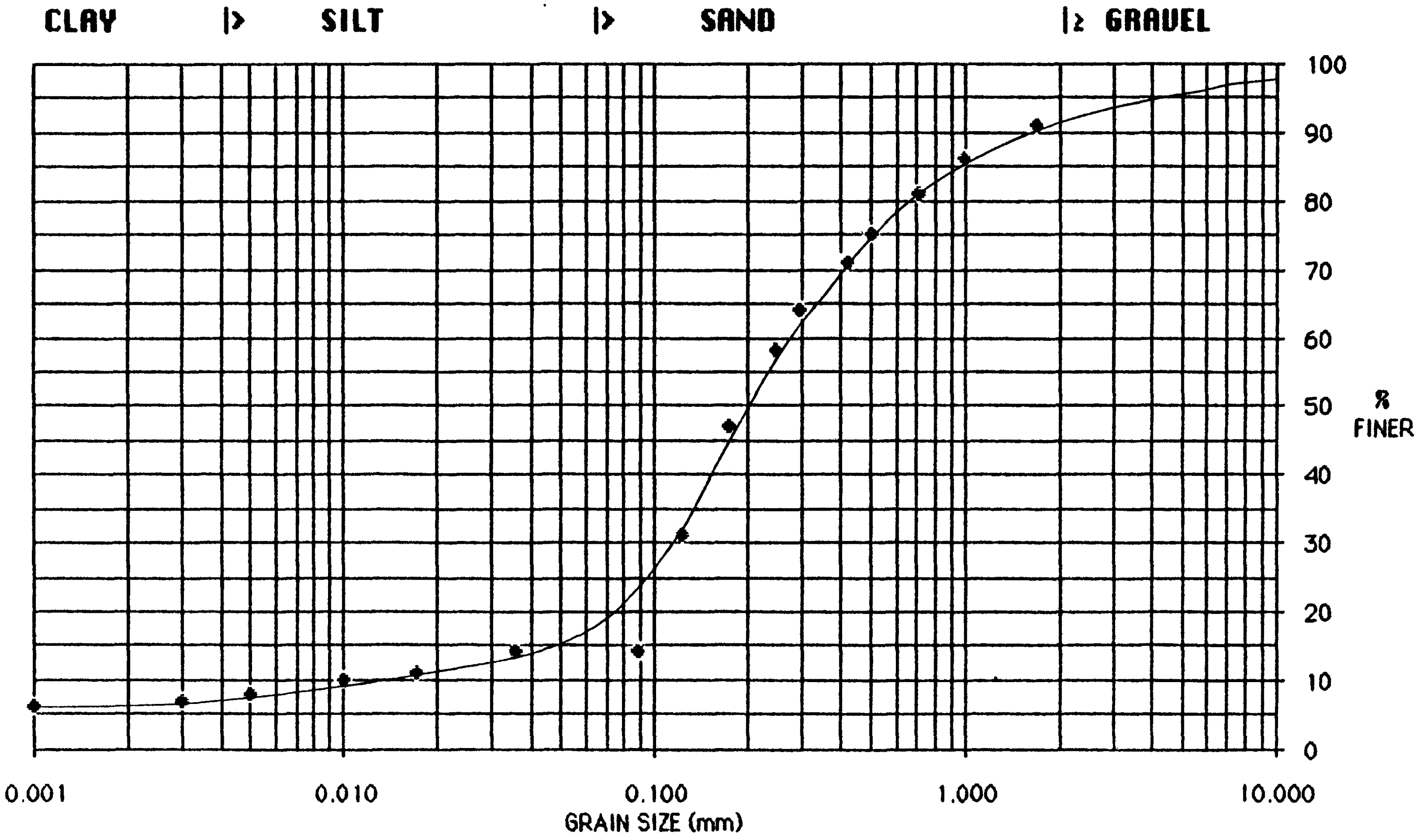


FIGURE 39.

SOIL PARTICLE-SIZE DISTRIBUTION
CAMP IRON MOUNTAIN

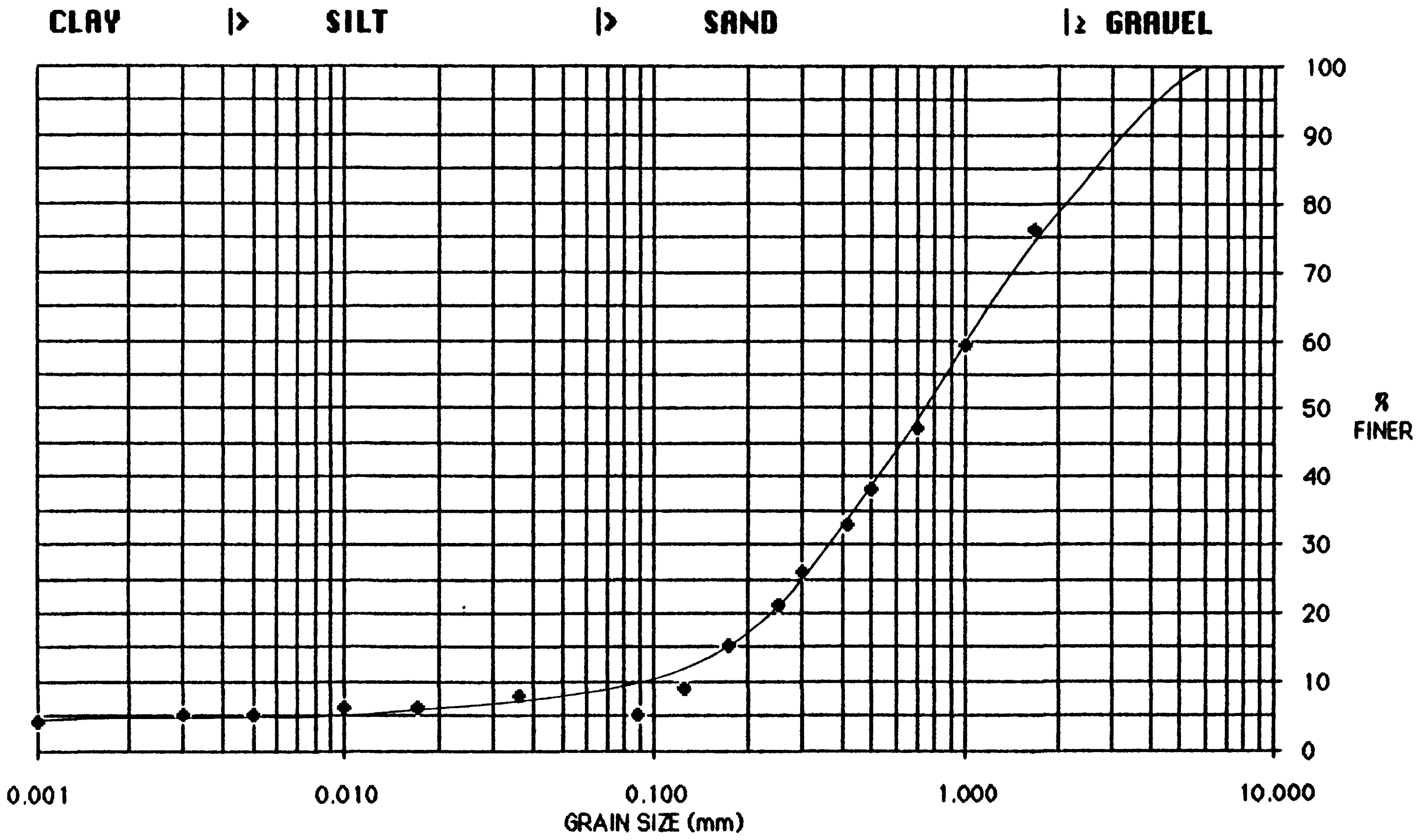


FIGURE 40.

SOIL PARTICLE-SIZE DISTRIBUTION
CAMP GRANITE

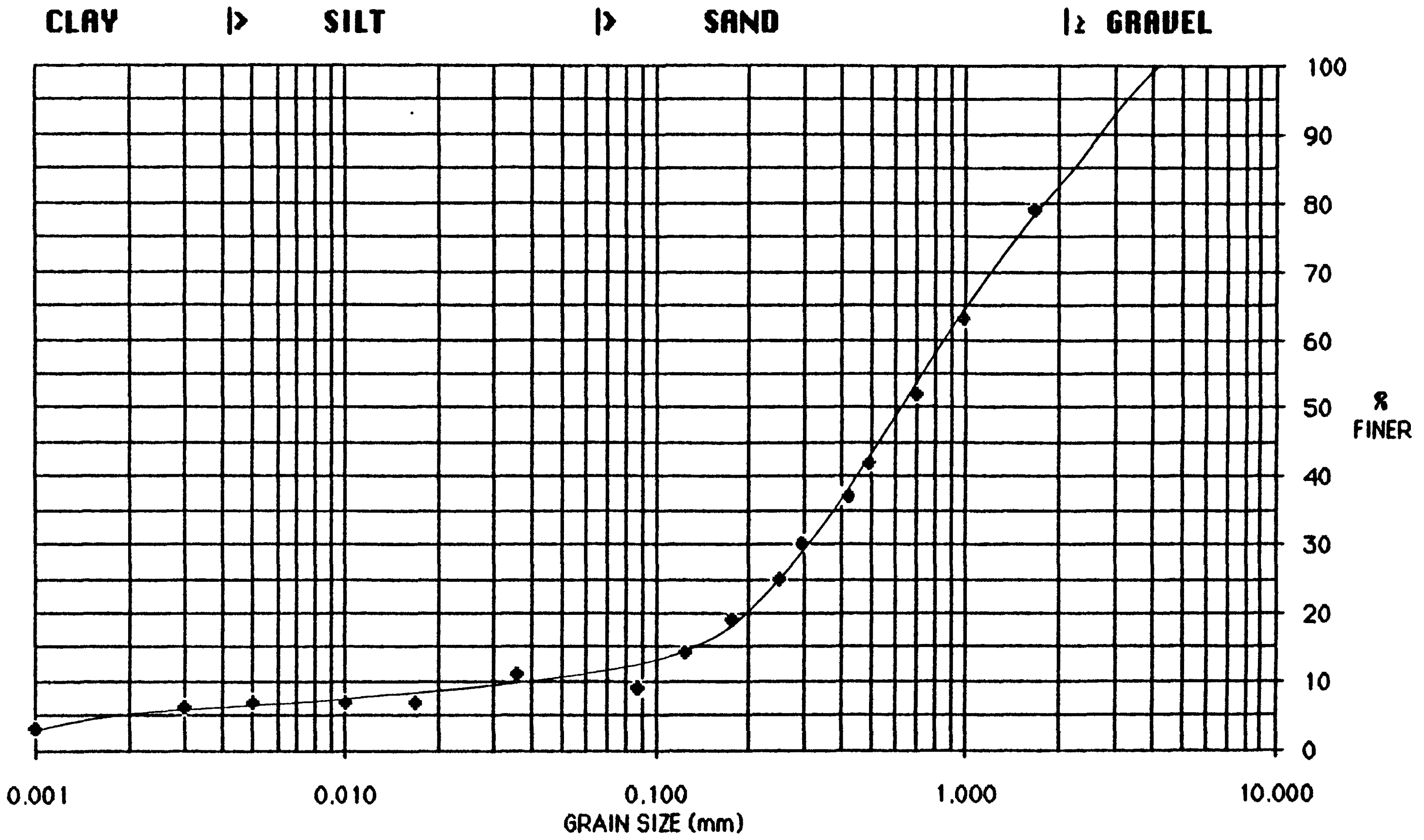
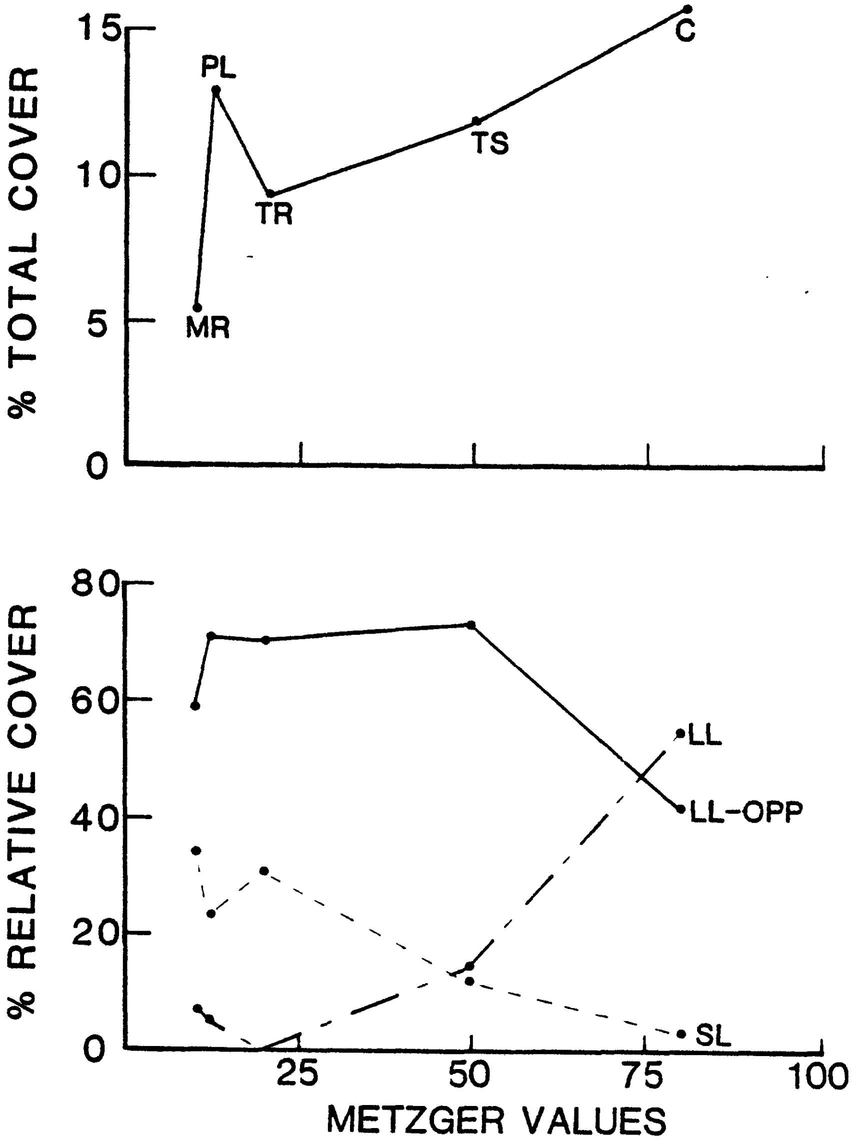


FIGURE 41a.

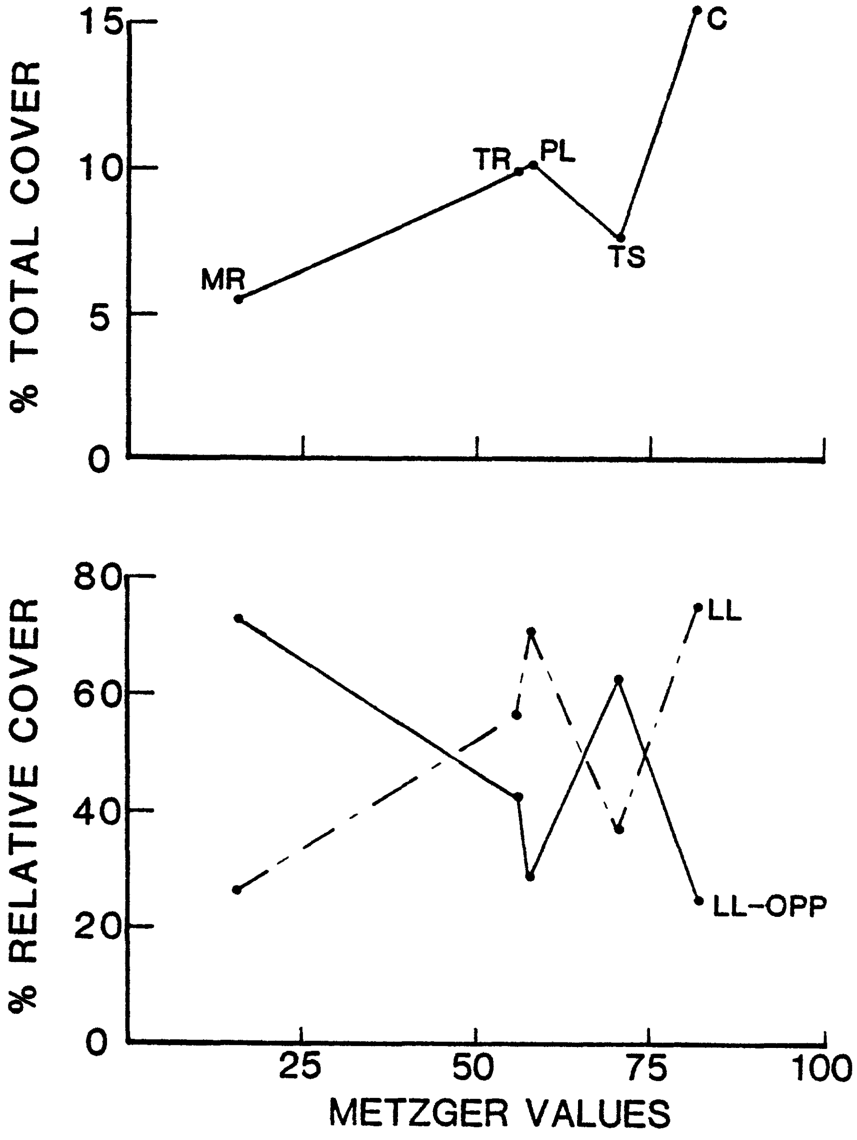
VEGETATIVE COVER
VS.
PENETROMETER RESISTANCE



Camp Ibis

FIGURE 41b.

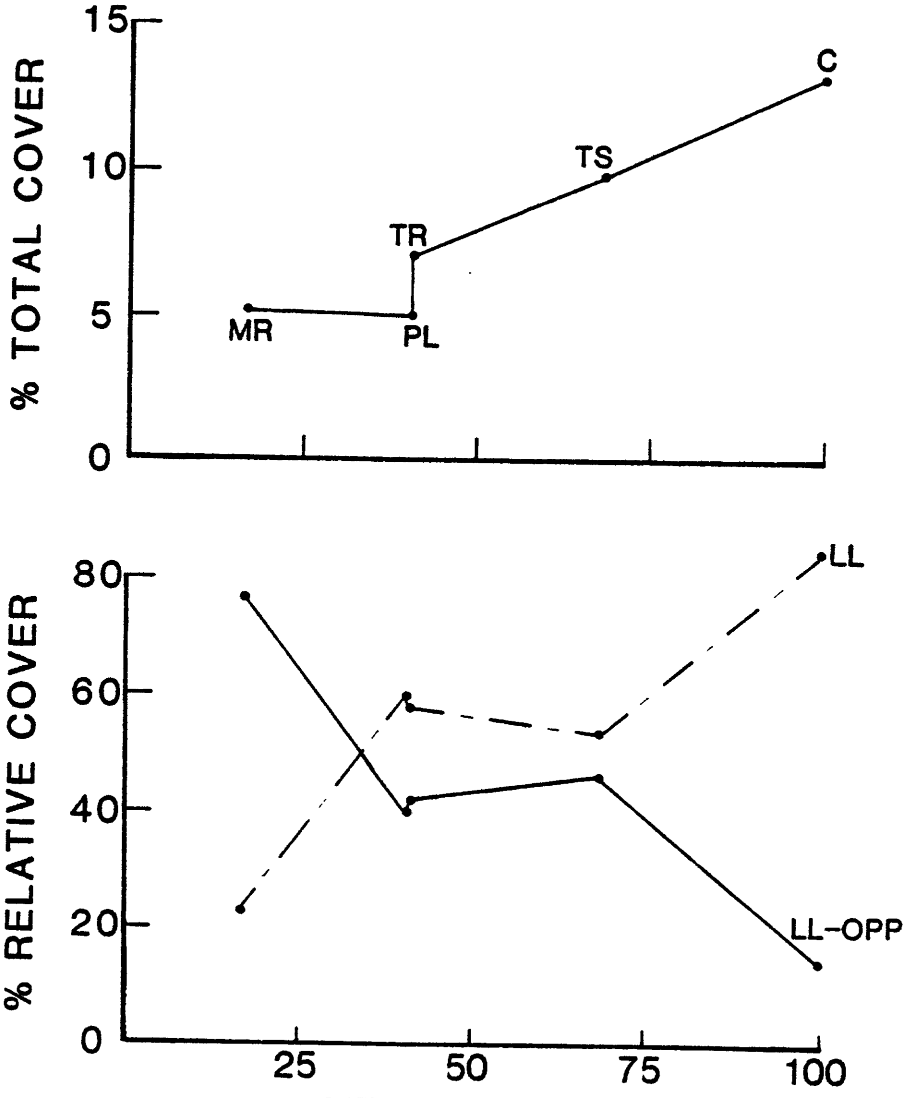
VEGETATIVE COVER
VS.
PENETROMETER RESISTANCE



Camp old Clipper

FIGURE 41c.

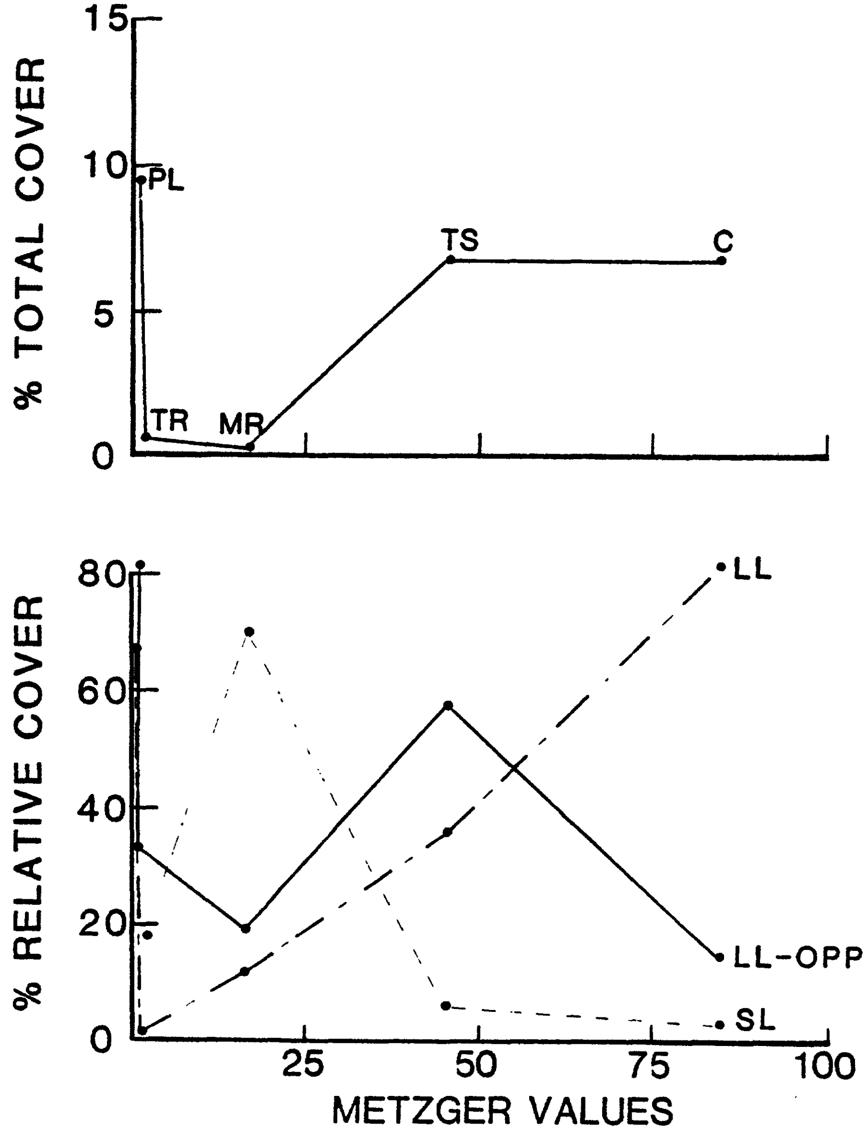
VEGETATIVE COVER
VS.
PENETROMETER RESISTANCE



Camp new Clipper

FIGURE 41d.

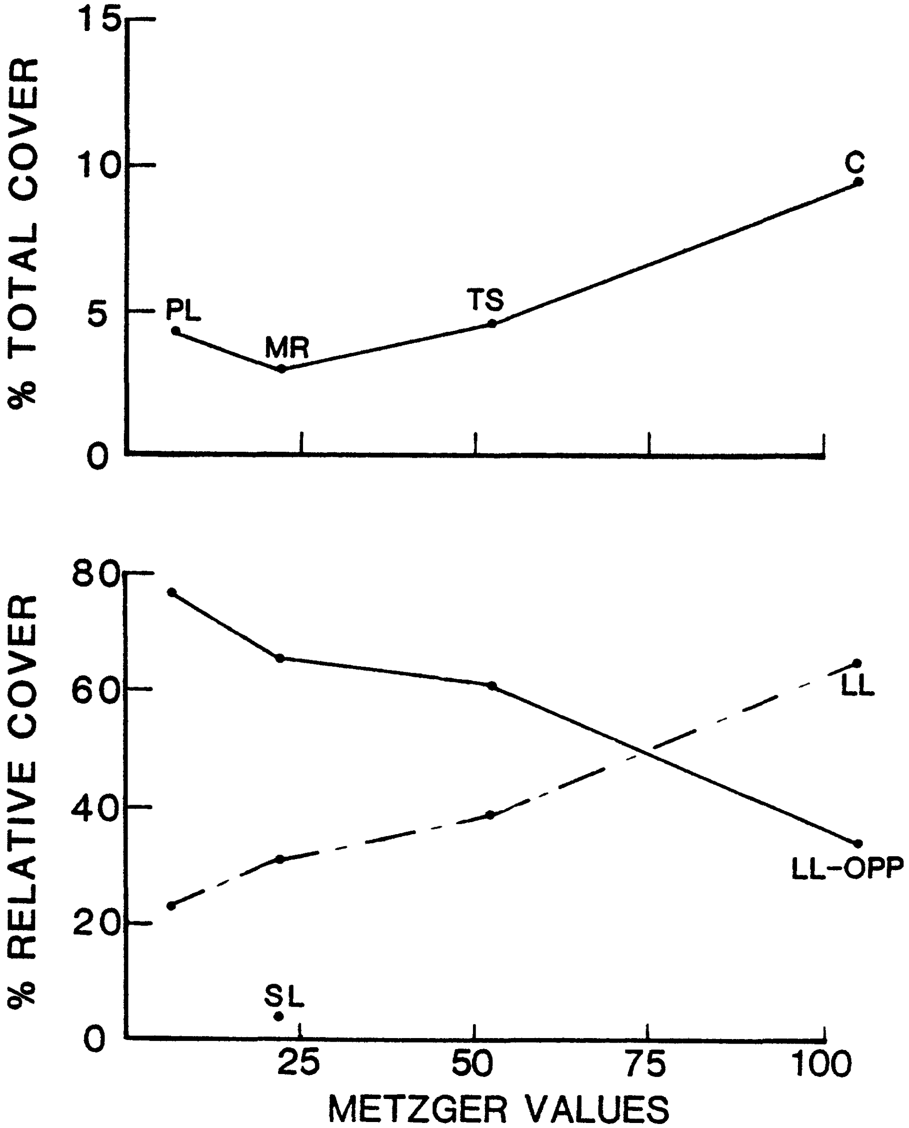
VEGETATIVE COVER
VS.
PENETROMETER RESISTANCE



Camp Iron Mountain

FIGURE 41e.

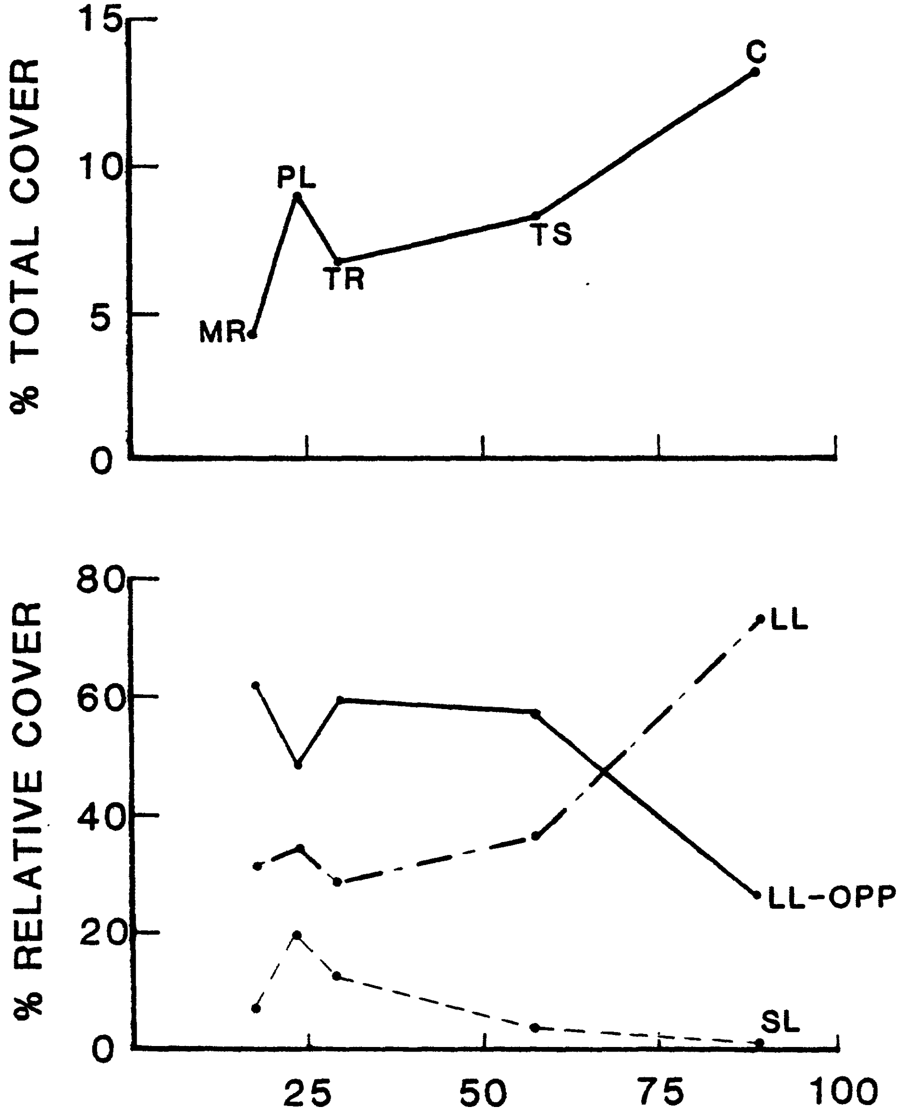
VEGETATIVE COVER
VS.
PENETROMETER RESISTANCE



Camp Granite

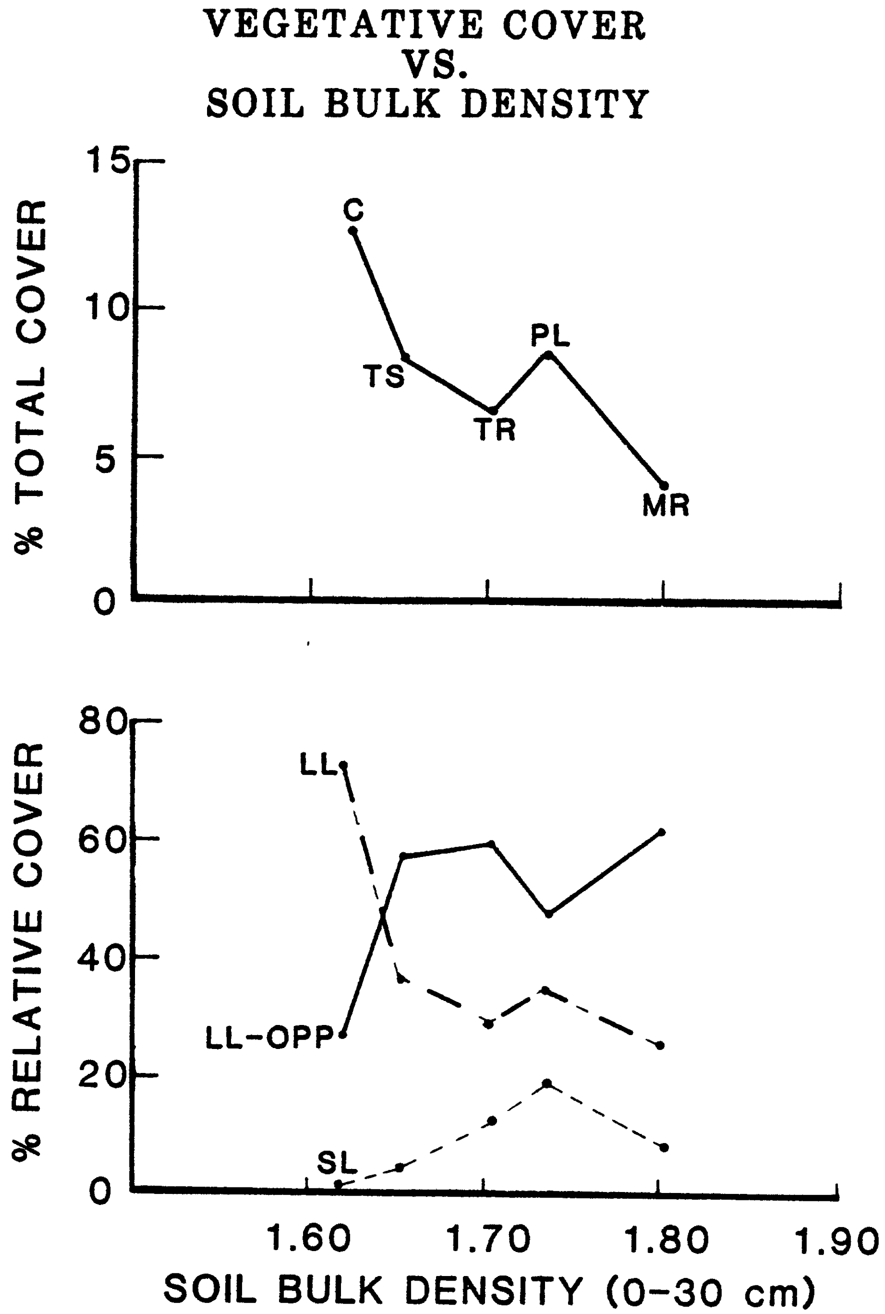
FIGURE 41f.

VEGETATIVE COVER VS. PENETROMETER RESISTANCE



COMBINED

FIGURE 42.



Vegetative cover vs. Soil bulk density for all camps combined.

TABLE 1.

Soil Characteristics for 5 Military Training Camps, Mojave Desert, California.

Camp Name	Lithology	$CaCO_3$ %	Depth to K-	Soil texture (USDA)
1) Ibis	.Precambrian granite .Tertiary volcanic	2.6%	30-60 cm	gravelly sand
2) Clipper, old	.Precambrian granite & metamorphic; Tertiary volcanic; Arkose	0%	>50 cm	loamy sand
3) Clipper, new	.same as #2	0.1%	>90 cm	loamy sand
4) Iron Mountain	.Mesozoic granite	0.5%	50-60 cm	gravelly sand
5) Granite	.Mesozoic granite & altered mafics	0.7%	40-50 cm	sand

TABLE 2.

☆ SOIL BULK DENSITY

CAMP IBIS

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth			
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	sig.
control	10	1.65	0.07	10	1.68	0.07	10	1.65	0.07	30	1.66	0.07	
tent site	10	1.74	0.05	10	1.67	0.06	10	1.73	0.09	30	1.70	0.06	*
tent road	10	1.82	0.08	10	1.75	0.11	5	1.66	0.07	25	1.76	0.11	**
parking lot	10	1.83	0.06	9	1.84	0.07	10	1.72	0.05	25	1.81	0.14	**
main road	10	1.79	0.14	8	1.90	0.22	4	1.81	0.08	22	1.84	0.17	**

* - significant at $t_{.95}$

** " $t_{.995}$

TABLE 3.

✡ WATER CONTENT (%total weight)

CAMP IBIS

CATEGORY	0-10cm		10-20 cm		20-30 cm		combined 0-30cm	
	n	%H20	n	%H20	n	%H20	n	%H20
control	10	0.9	10	1.7	10	2.2	30	1.6
tent site	10	1.1	10	1.8	10	1.9	30	1.6
tent road	10	1.3	10	2.1	5	2.3	25	1.8
parking lot	10	1.2	9	2.0	6	2.3	25	1.7
main road	10	1.9	8	2.4	4	3.0	22	2.3

TABLE 4.

✡ CALCIUM CARBONATE -weight %

CAMP IBIS

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth		
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	
control	12	2.5	0.5	12	2.2	0.6	12	3.0	0.7	36	2.6	
tent site	12	2.0	0.5	12	2.5	0.7	12	2.4	0.4	36	2.3	
parking lot	16	3.5	1.4	16	3.3	0.9	12	2.9	1.1	46	3.2	
main road	12	3.5	0.8	12	4.3	2.2	8	2.5	0.5	32	3.4	

TABLE 5.

☆ SOIL BULK DENSITY

CAMP CLIPPER 'OLD'

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth			
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	sig.
control	10	1.55	0.05	10	1.56	0.05	10	1.54	0.03	30	1.55	0.04	
tent site	10	1.56	0.06	10	1.58	0.05	10	1.58	0.04	30	1.57	0.05	*
tent road	10	1.63	0.05	10	1.57	0.06	10	1.62	0.04	30	1.61	0.06	**
parking lot	10	1.60	0.05	10	1.65	0.07	10	1.63	0.05	30	1.63	0.06	**
main road	10	1.75	0.03	10	1.73	0.08	10	1.68	0.05	30	1.72	0.06	**

* - significant at $t_{.95}$
** " $t_{.995}$

TABLE 6.

✡ WATER CONTENT (%total weight)

CAMP CLIPPER 'OLD'

CATEGORY	0-10cm		10-20 cm		20-30 cm		combined 0-30cm	
	n	%H20	n	%H20	n	%H20	n	%H20
control	10	0.6	10	1.5	10	2.2	30	1.4
tent site	10	0.8	10	1.6	10	2.5	30	1.6
tent road	10	0.9	10	1.8	10	2.2	30	1.6
parking lot	10	1.1	10	1.7	10	2.2	30	1.7
main road	10	0.8	10	1.6	10	2.1	30	1.5

TABLE 7.

✡ CALCIUM CARBONATE -weight %

CAMP CLIPPER 'OLD'

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth		
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	
control	12	0	--	12	0	--	12	0	--	36	0	
parking lot	12	0	--	12	0.1	0.1	12	0.1	0.1	36	0.1	
main road	4	0	--	4	0	--	4	0	--	12	0	

TABLE 8.

☆ SOIL BULK DENSITY

CAMP CLIPPER 'NEW'

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth			
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	sig.
control	10	1.53	0.06	10	1.59	0.05	10	1.59	0.10	30	1.57	0.08	
tent site	10	1.62	0.06	10	1.58	0.07	10	1.61	0.08	30	1.60	0.07	
tent road	10	1.67	0.06	10	1.61	0.04	10	1.64	0.06	30	1.64	0.06	**
parking lot	10	1.60	0.04	10	1.57	0.05	10	1.55	0.10	30	1.57	0.07	
main road	10	1.80	0.07	10	1.85	0.08	10	1.76	0.10	30	1.80	0.09	**

* - significant at $t_{.95}$

** " $t_{.995}$

TABLE 9.

✡ WATER CONTENT (%total weight)

CAMP CLIPPER 'NEW'

CATEGORY	0-10cm		10-20 cm		20-30 cm		combined 0-30cm	
	n	%H20	n	%H20	n	%H20	n	%H20
control	10	1.1	10	2.2	10	2.6	30	1.9
tent site	10	1.8	10	2.8	10	3.4	30	2.7
tent road	10	1.5	10	2.2	10	2.7	30	2.1
parking lot	10	1.7	10	3.2	10	3.6	30	2.8
main road	10	1.8	10	2.1	9	2.0	29	1.9

TABLE 10.
✡ CALCIUM CARBONATE -weight %

CAMP CLIPPER 'NEW'

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth		
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	
control	12	0	--	12	0	--	12	0.3	0.2	36	0.1	
tent site	12	0.8	0.6	12	0.2	0.2	12	0.2	0.2	36	0.4	
parking lot	12	0.6	0.2	12	0.9	0.6	12	0.5	0.2	36	0.6	

TABLE 11.

☆ SOIL BULK DENSITY

CAMP IRON MOUNTAIN

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth			
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	sig.
control	10	1.65	0.06	10	1.70	0.05	10	1.74	0.05	10	1.70	0.06	
tent site	10	1.77	0.05	10	1.74	0.06	10	1.73	0.04	30	1.75	0.05	**
tent road	10	1.86	0.08	10	1.85	0.06	10	1.75	0.02	30	1.82	0.07	**
parking lot	10	1.83	0.04	10	1.86	0.06	10	1.75	0.04	30	1.81	0.07	**
main road	10	1.93	0.05	10	1.88	0.06	7	1.78	0.05	27	1.87	0.08	**

* - significant at $t_{.95}$

** " $t_{.995}$

TABLE 12.

☆ WATER CONTENT (%total weight)

CAMP IRON MOUNTAIN

CATEGORY	0-10cm		10-20 cm		20-30 cm		combined 0-30cm	
	n	%H20	n	%H20	n	%H20	n	%H20
control	10	0.4	10	0.4	10	0.6	30	0.5
tent site	10	0.3	10	0.4	10	0.5	30	0.5
tent road	10	0.4	10	0.5	10	1.0	30	0.6
parking lot	10	0.3	10	0.4	10	0.7	30	0.4
main road	10	0.3	10	1.3	7	1.1	27	0.6

TABLE 13.

✡ CALCIUM CARBONATE -weight %

CAMP IRON MOUNTAIN

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth		
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	
control	12	0.5	0.2	12	0.5	0.1	12	0.5	0.2	36	0.5	
tent site	8	0.5	0.1	12	0.4	0.1	12	0.6	0.3	32	0.5	
parking lot	12	0.4	0.1	12	0.5	0.2	12	0.5	0.2	36	0.5	

TABLE 14.

☆ SOIL BULK DENSITY

CAMP GRANITE

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth			
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	sig.
control	10	1.54	0.05	10	1.63	0.05	10	1.64	0.07	30	1.60	0.07	
tent site	10	1.65	0.05	10	1.72	0.07	10	1.70	0.03	30	1.70	0.06	**
parking lot	10	1.82	0.07	10	1.86	0.03	9	1.80	0.03	29	1.83	0.05	**
main road	10	1.81	0.09	10	1.87	0.05	10	1.76	0.07	30	1.81	0.09	**

* - significant at $t_{.95}$

** " $t_{.995}$

TABLE 15.

✡ WATER CONTENT (%total weight)

CAMP GRANITE

CATEGORY	0-10cm		10-20 cm		20-30 cm		combined 0-30cm	
	n	%H20	n	%H20	n	%H20	n	%H20
control	10	0.4	10	0.4	10	0.5	30	0.4
tent site	10	0.4	10	0.3	10	0.4	30	0.4
tent road (no rdngs.)								
parking lot	10	0.4	10	0.4	9	0.7	29	0.5
main road	10	0.2	10	0.5	10	0.7	30	0.5

TABLE 16.

✡ CALCIUM CARBONATE -weight %

CAMP GRANITE

CATEGORY	0-10 cm depth			10-20 cm depth			20-30 cm depth			combined 0-30 cm depth		
	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	
control	12	0.7	0.2	12	0.7	0.2	12	0.6	0.1	36	0.7	

TABLE 17. RELATIVE DENSITY (expressed as % of TOTAL density) of perennial shrub species by functional group for five abandoned WW II military camps.

1 = control, 2 = tent sites, 3 = tent roads, 4 = parking lot, 5 = main roads.

SPECIES	CAMP IBIS					CAMP OLD CLIPPER					CAMP NEW CLIPPER					CAMP IRON MT.					CAMP GRANITE MT.			
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	4	5
Long-lived																								
Atriplex polycarpa																					3.8		2.9	
Encelia farinosa				0.8													0.7		0.8	40.1				
Krameria parvifolia	15.3																							
Larrea tridentata	11.3	3.1		1.6	2.5	75.3	36.8	56.6	71.0	26.2	35.0	16.6	24.4	21.2	12.5	42.8	6.7	4.1	3.7		15.3	5.3	5.9	5.4
Lepidium fremontii																	1.3		2.2					
Opuntia echinocarpa											3.6										7.7			2.8
Opuntia ramosissima	1.6																				2.0			
Yucca achidigera	2.4																							
Long-lived opportunistic																								
Ambrosia dumosa	57.3	74.5	66.7	65.7	46.3	24.7	63.2	43.4	29.0	73.8	61.4	83.4	75.6	78.8	87.5	49.9	86.0	75.8	33.1	59.9	71.2	93.4	88.3	83.8
Short-lived																								
Bebbia juncea																3.6								
Dyssodia porophylloides	1.6																							
Encelia frutescens	6.4	11.2	18.6	28.6	48.7																			
Hymenoclea salsola		6.1	2.7	0.8													4.0	4.1	55.9					
Porophyllum gracile		4.1	4.0	0.8																				
Stephanomeria pauciflora	4.0	1.0	8.0	1.6	2.5											3.6	1.3	16.0	4.4			1.3	2.9	8.1
TOTAL DENSITY (no ha^{-1})	5165	4084	3409	5250	1709	2425	2750	2500	1400	1225	2075	1800	1025	825	800	467	2500	418	2267	167	867	1267	1133	617

TABLE 18. RELATIVE COVER (expressed as % of TOTAL cover) of perennial shrub species by functional group for five abandoned WW II military camps.

1 = control, 2 = tent sites, 3 = tent roads, 4 = parking lot, 5 = main roads; * t = less than 0.1.

SPECIES	CAMP IBIS					CAMP OLD CLIPPER					CAMP NEW CLIPPER					CAMP IRON MT.					CAMP GRANITE MT.			
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	4	5
Long-lived																								
<u>Atriplex polycarpa</u>																					1.5		1.9	2.8
<u>Encelia farinosa</u>				1.5													1.2		0.5	66.7				
<u>Krameria parvifolia</u>	11.2																							
<u>Larrea tridentata</u>	42.1	14.5		3.9	7.1	75.3	36.8	56.6	71.0	26.2	85.4	53.5	57.7	60.0	23.2	82.4	33.1	0.9	9.7		59.3	39.0	20.5	28.0
<u>Lepidium fremontii</u>																	1.9		1.5					
<u>Opuntia echinocarpa</u>											0.2										2.4			t
<u>Opuntia ramosissima</u>	0.6																				2.4			
<u>Yucca schidigera</u>	0.6																							
Total Relative Cover(%) of long-lived species	54.5	14.5	0	5.4	7.1	75.3	36.8	56.6	71.0	26.2	85.6	53.5	57.7	60.0	23.2	82.4	36.2	0.9	11.7	66.7	65.6	39.0	22.4	30.8
Long-lived opportunistic																								
<u>Ambrosia dumosa</u>	42.1	73.5	70.2	71.3	58.9	24.7	63.2	43.4	29.0	73.8	14.4	46.5	42.3	40.0	76.8	14.7	58.0	81.1	19.1	33.3	34.4	60.7	77.1	65.4
Short-lived																								
<u>Bebbia juncea</u>																1.8								
<u>Dyssodia porophylloides</u>	0.5																							
<u>Encelia frutescens</u>	2.0	3.4	10.9	20.5	33.0																			
<u>Hymenoclea salsola</u>		7.7	12.5	2.6													5.5	3.0	68.5					
<u>Porophyllum gracile</u>		0.8	3.8	0.4																				
<u>Stephanomeria pauciflora</u>	0.9	t*	2.6	0.5	0.9											1.1	0.3	0.6	14.2			0.2	0.5	3.8
Total Relative Cover(%) of short-lived species	3.4	12.0	29.8	23.3	33.9											2.9	5.8	3.6	82.7			0.2	0.5	3.8
TOTAL COVER (%)	17.7	11.7	9.3	13.0	5.6	15.4	7.7	9.9	10.7	6.1	13.2	10.0	7.1	5.0	5.6	6.7	6.8	1.1	9.4	0.8	9.6	4.5	4.0	2.6

TABLE 19. Percent difference between disturbed areas and adjacent controls for density and cover of perennial shrubs in five abandoned WW II military camps.

K = number of 20 m^2 quadrats (Ibis) or number of 20 m^2 intervals (all other camps); N = number of plants counted; N/N = number of whole plants measured/number of partial plants measured; * - = reduction, + = increase.

	K	N	DENSITY (No. ha^{-1})	% difference from CONTROL *	N/N	COVER (%)	% difference from CONTROL
CAMP IBIS							
Control	12	124	5165		124	17.7	
Tent Sites	12	98	4084	-21.0	98	11.7	-33.9
Tent Roads	12	75	3409	-34.0	75	9.3	-47.4
Parking Lot	12	126	5250	+1.6	126	13.0	-26.6
Main Roads	12	41	1709	-66.9	41	5.6	-68.4
CAMP OLD CLIPPER							
Control	20	97	2425		82/33	15.4	
Tent Sites	20	110	2750	+13.4	101/19	7.7	-50.0
Tent Roads	20	100	2500	+3.1	88/17	9.9	-35.7
Parking Lot	20	57	1400	-42.3	51/14	10.7	-30.5
Main Roads	20	49	1225	-49.5	43/10	6.1	-60.4
CAMP NEW CLIPPER							
Control	20	83	2075		66/25	13.2	
Tent Sites	20	72	1800	-13.2	56/33	10.0	-24.2
Tent Roads	20	41	1025	-50.6	30/19	7.1	-46.2
Parking Lot	20	33	825	-60.2	29/9	5.0	-62.1
Main Roads	20	32	800	-61.4	28/8	5.6	-57.6
CAMP IRON MOUNTAIN							
Control	30	26	467		19/13	6.7	
Tent Sites	30	150	2500	+435.3	142/15	6.8	+1.5
Tent Roads	30	25	418	-10.5	22/4	1.1	-83.6
Parking Lot	30	136	2267	+385.4	124/21	9.4	+40.3
Main Roads	30	10	167	-64.2	8/2	0.8	-88.0
CAMP GRANITE							
Control	30	52	867		43/25	9.6	
Tent Sites	30	76	1267	+46.1	64/27	4.5	-53.1
Parking Lot	30	68	1133	+30.7	60/15	4.0	-58.3
Main Roads	30	31	617	-28.8	32/13	2.6	-72.9

Table 20. Density and cover of the annual vegetation, herbaceous perennial vegetation, and cryptogamic crust in four abandoned WW II military camps.

D = density expressed as number of plants per 1 m^2; C = cover expressed as % ground cover; 1 = control, 2 = tent sites, 3 = tent roads, 4 = parking lot, 5 = main roads. * = due to their abundance, the figures for this grass include remaining dead clumps as well as the relatively few that were still alive; ** = t, less than 0.1; += R=relief lichen, F=flat lichen.

SPECIES	CAMP OLD CLIPPER 1		2		3		4		5	
	D	C	D	C	D	C	D	C	D	C
Annuals										
Cryptantha nevadensis			0.2	t**	0.1	t	0.6	t	0.3	t
Plantago insularis	8.4	0.7	1.3	0.2	1.8	0.2	7.4	1.1	0.5	0.1
*Schismus arabicus**	3.7	2.0	9.2	3.3	9.9	4.1	12.5	6.6	0.4	t
Herbaceous perennials										
Allionia incarnata										
Baileya multiradiata			0.6	0.4			0.3	0.4		
Dalea mollis										
Euphorbia polycarpa										
Hilaria rigida	0.1	1.5								
Parafoxia linearis										
Total Density	12.2		11.3		11.8		20.8		1.2	
Total Cover		4.2		3.9		4.3		8.2		0.2
Cryptogamic crust										
Heppia lutosa										
relief										
flat										
Total cover										
R/F ratio +										
No. of 1.0 m^2 plots/category	20									
No. of 0.1 m^2 plots/category	100									

SPECIES	CAMP NEW CLIPPER 1		2		3		4		5	
	D	C	D	C	D	C	D	C	D	C
Annuals										
Cryptantha nevadensis	0.1	t	0.6	t	1.1	0.3				1.1
Plantago insularis	12.7	1.5	0.5	0.1					3.1	0.5
*Schismus arabicus**										
Herbaceous perennials										
Allionia incarnata			0.1	t						
Baileya multiradiata										
Dalea mollis			0.1	0.2					t	
Euphorbia polycarpa										
Hilaria rigida										
Parafoxia linearis										
Total Density	12.8		1.3		1.1		0		4.2	
Total Cover		1.5		0.4		0.3		0		0.7
Cryptogamic crust										
Heppia lutosa										
relief										
flat										
Total cover										
R/F ratio +										
No. of 1.0 m^2 plots/category	20									
No. of 0.1 m^2 plots/category	100									

SPECIES	CAMP IRON MOUNTAIN 1		2		3		4		5	
	D	C	D	C	D	C	D	C	D	C
Annuals										
Cryptantha nevadensis	0.2									
Plantago insularis	t		t		t				t	
*Schismus arabicus**	t		t		t		t			
Herbaceous perennials										
Allionia incarnata										
Baileya multiradiata										
Dalea mollis										
Euphorbia polycarpa	3.6	7.9	2.4	8.3	0.9	3.2	0.9	2.1	0.9	1.4
Hilaria rigida										
Parafoxia linearis										
Total Density	3.6		2.4		0.9		0.9		0.9	
Total Cover		7.9		8.3		3.2		2.1		1.4
Cryptogamic crust										
Heppia lutosa										
relief		14.2		3.5		1.8		1.8		1.0
flat		17.2		17.8		15.7		22.5		4.2
Total cover		31.4		21.3		17.5		24.3		5.2
R/F ratio +		.82		.20		.11		.08		.24
No. of 1.0 m^2 plots/category	30									
No. of 0.1 m^2 plots/category	150									

SPECIES	CAMP GRANITE 1		2		4		5	
	D	C	D	C	D	C	D	C
Annuals								
Cryptantha nevadensis								
Plantago insularis	1.5	0.2	1.1	0.2	t			
*Schismus arabicus**								
Herbaceous perennials								
Allionia incarnata								
Baileya multiradiata								
Dalea mollis								
Euphorbia polycarpa	3.5	3.7			t		1.8	2.2
Hilaria rigida								
Parafoxia linearis								
Total Density	5.0		1.1		t		1.8	
Total Cover		3.9		0.2	t			2.2
Cryptogamic crust								
Heppia lutosa								
relief		26.2		10.3		11.2		8.0
flat		17.2		25.9		23.0		13.7
Total cover		43.4		36.2		34.2		21.7
R/F ratio +		1.50		.40		.49		.58
No. of 1.0 m^2 plots/category	30							
No. of 0.1 m^2 plots/category	150							

TABLE 21. Time yet required (in years) for *Larrea tridentata* in disturbed areas to attain control densities.

	CAMPS			
	old Clipper	new Clipper	Iron Mountain	Granite
Tent Sites	112 yrs	75 yrs	8 yrs	53 yrs
Tent Roads	57 yrs	84 yrs	440 yrs	
Parking Lots	35 yrs	440 yrs.	40yrs	53 yrs
Main Roads	112 yrs	500 yrs	infinity	100 yrs

APPENDIX

Individual bulk density sample data. Each sample has a volume of 224.8 cm^3. Water content calculated from corresponding bulk density sample.

appendix a. IBIS

category	sample name	bulk density	H_2O content
Control	1-A *	1.66	0.80
	-B **	1.69	1.70
	-C ***	1.65	1.88
	2-A	1.72	0.94
	-B	1.68	1.62
	-C	1.62	2.08
	3-A	1.68	0.76
	-B	1.58	1.75
	-C	1.60	2.10
	4-A	1.51	0.94
	-B	1.66	1.32
	-C	1.52	2.03
	5-A	1.57	0.74
	-B	1.60	1.90
	-C	1.68	2.87
	6-A	1.60	1.00
	-B	1.70	2.16
	-C	1.55	2.70
	7-A	1.64	1.20
	-B	1.60	2.35
	-C	1.69	2.14
	8-A	1.72	0.90
	-B	1.76	1.83
	-C	1.72	2.00
	35-A	1.64	0.76
	-B	1.78	1.32
	-C	1.72	2.54
	36-A	1.72	1.02
	-B	1.78	1.24
	-C	1.74	1.39
Tent Site	20-A	1.68	1.31
	-B	1.68	1.31
	-C	1.71	2.19
	21-A	1.77	1.11
	-B	1.57	1.55
	-C	1.64	1.66
	22-A	1.72	0.97
	-B	1.71	1.77
	-C	1.77	1.92
	23-A	1.74	1.19
	-B	1.75	2.32
	-C	1.72	1.96
	24-A	1.77	1.23
	-B	1.69	2.04

* -A samples are from the 0-10 cm soil depth. -B = 10-20 cm depth. -C = 20-30 cm.

IBIS, PAGE II

	-C	1.70	2.06
	46-A	1.80	1.14
	-B	1.68	1.75
	-C	1.67	1.76
	47-A	1.75	1.14
	-B	1.71	1.40
	-C	1.63	1.84
	48-A	1.76	0.80
	-B	1.56	1.95
	-C	1.71	1.69
	49-A	1.75	0.96
	-B	1.62	1.96
	-C	1.72	1.93
	50-A	1.62	1.04
	-B	1.72	1.73
	-C	1.71	1.57
Tent Road	27-A	1.82	1.50
	-B	1.79	2.28
	-C	1.52	3.12
	28-A	1.80	1.24
	-B	1.53	2.52
	29-A	1.86	1.80
	-B	1.82	2.46
	30-A	1.86	1.98
	-B	1.80	2.59
	-C	1.70	2.52
	31-A	1.83	1.67
	-B	1.77	2.44
	-C	1.69	2.61
	51-A	1.78	0.96
	-B	1.74	1.70
	52-A	1.90	0.98
	-B	1.81	1.53
	-C	1.72	1.64
	53-A	1.92	1.09
	-B	1.89	1.51
	-C	1.66	1.74
	54-A	1.84	1.10
	-B	1.81	1.32
	55-A	1.62	1.07
	-B	1.55	2.62
Parking Lot	9-A	1.91	1.15
	-B	1.90	1.77
	10-A	1.81	1.42
	11-A	1.72	0.74
	-B	2.36	1.29
	12-A	1.75	1.19
	-B	1.54	2.06
	-C	1.63	2.29
	13-A	1.83	1.39

IBIS, PAGE III

	-B	1.82	1.66
	-C	1.77	1.94
	14-A	1.27	1.20
	-B	1.82	2.06
	-C	1.72	2.10
	37-A	1.81	1.49
	-B	1.73	2.85
	38-A	1.81	1.14
	-B	1.73	1.93
	-C	1.74	2.65
	39-A	1.84	1.23
	-B	1.77	2.49
	-C	1.67	2.53
	40-A	1.91	1.25
	-B	1.92	1.73
	-C	1.76	2.12
Road	15-A	1.59	2.90
	-B	1.88	4.54
	16-A	1.75	1.46
	-B	1.56	3.32
	17-A	1.92	1.67
	-B	2.40	2.79
	18-A	1.60	3.21
	19-A	1.63	3.36
	41-A	1.77	0.56
	-B	1.80	1.23
	-C	1.91	2.22
	42-A	1.89	1.42
	-B	1.95	1.74
	-C	1.78	1.94
	43-A	1.99	1.29
	-B	1.90	1.89
	44-A	1.85	1.59
	-B	1.85	2.09
	-C	1.85	1.74
	45-A	1.95	1.15
	-B	1.88	1.96
	-C	1.69	5.93

appendix b.

OLD CLIPPER

category	sample name	bulk density	H_2O content
Control	54-A	1.59	0.6%
	-B	1.56	1.3
	-C	1.53	2.2
	55-A	1.53	0.8
	-B	1.59	1.4
	-C	1.59	2.2
	56-A	1.49	0.9
	-B	1.46	2.9
	-C	1.55	3.8
	57-A	1.62	0.4
	-B	1.63	1.2
	-C	1.58	2.9
	58-A	1.62	6.4
	-B	1.54	1.1
	-C	1.53	1.6
	59-A	1.58	0.3
	-B1	1.57	0.6
	-C	1.55	1.3
	60-A	1.56	0.5
	-B	1.56	1.3
	-C	1.58	1.3
	61-A	1.53	0.5
	-B	1.57	1.9
	-C	1.50	2.8
	62-A	1.52	0.5
	-B	1.60	1.0
	-C	1.54	1.8
	63-A	1.46	0.7
	-B	1.49	2.1
	-C	1.47	2.4
Tent Site	74-A	1.58	0.8
	-B	1.57	1.6
	-C	1.60	3.0
	75-A	1.65	0.7
	-B	1.67	2.0
	-C	1.61	2.8
	76-A	1.61	1.0
	-B	1.56	2.3
	-C	1.56	3.0
	77-A	1.46	0.7
	-B	1.65	1.6
	-C	1.58	2.3
	78-A	1.59	0.9
	-B	1.53	1.9

OLD CLIPPER, PAGE II

	-C	1.55	2.5
	79-A	1.46	0.5
	-B	1.58	0.8
	-C	1.67	1.5
	80-A	1.59	0.8
	-B	1.65	1.5
	-C	1.58	2.2
	81-A	1.51	0.7
	-B	1.51	1.6
	-C	1.54	2.6
	82-A	1.55	1.7
	-B	1.57	1.5
	-C	1.56	2.5
	83-A	1.58	0.7
	-B	1.52	1.5
	-C	1.57	2.2
Tent Road	84-A	1.64	0.9
	-B	1.54	1.6
	-C	1.57	2.4
	85-A	1.64	0.9
	-B	1.57	1.9
	-C	1.65	2.6
	86-A	1.68	1.2
	-B	1.66	2.4
	-C	1.13	1.9
	87-A	1.69	0.9
	-B	1.53	1.5
	-C	1.60	1.6
	88-A	1.66	0..7
	-B	1.58	1.4
	-C	1.64	2.1
	89-A	1.66	1.0
	-B	1.61	1.6
	-C	1.60	2.0
	90-A	1.56	1.1
	-B	1.46	2.8
	-C	1.59	2.5
	91-A	1.56	1.2
	-B	1.62	1.7
	-C	1.61	2.0
	92-A	1.69	0.8
	-B	1.51	1.7
	-C	1.57	2.6
	93-A	1.58	0.8
	-B	1.59	1.5
	-C	1.64	2.1
Parking Lot	94-A	1.51	0.7
	-B	1.51	1.8
	-C	1.58	2.6
	95-A	1.57	0.3

OLD CLIPPER, PAGE III

	-B	1.69	0.9
	-C	1.56	1.6
	96-A	1.63	0.9
	-B	1.61	2.2
	-C	1.68	2.5
	97-A	1.60	0.8
	-B	1.69	1.4
	-C	1.59	2.1
	98-A	1.56	1.6
	-B	1.68	1.6
	-C	1.65	2.1
	99-A	1.72	1.1
	-B	1.78	1.3
	-C	1.69	1.8
	100-A	1.60	1.0
	-B	1.70	1.4
	-C	1.66	2.0
	101-A	1.65	1.7
	-B	1.14	2.1
	-C	1.68	2.3
	102-A	1.56	1.4
	-B	1.61	1.9
	-C	1.56	2.8
	103-A	1.61	1.8
	-B	1.60	2.3
	-C	1.70	2.0
Road	64-A	1.75	0.7
	-B	1.74	1.5
	-C	1.65	2.1
	65-A	1.75	0.7
	-B	1.68	1.6
	-C	1.66	2.3
	66-A	1.17	1.0
	-B	1.85	1.4
	-C	1.78	2.0
	67-A	1.76	0.7
	-B	1.74	1.7
	-C	1.68	1.9
	68-A	1.67	1.0
	-B	1.62	1.8
	-C	1.57	2.1
	69-A	1.76	0.7
	-B	1.57	1.3
	-C	1.65	1.8
	70-A	1.75	1.8
	-B	1.75	1.7
	-C	1.67	2.0
	71-A	1.73	0.8
	-B	1.74	2.0
	-C	1.71	2.5
	72-A	1.76	1.2
	-B	1.76	1.9

OLD CLIPPER, PAGE IIII

-C	1.73	2.1
73-A	1.77	0.7
-B	1.80	1.6
-C	1.68	1.8

appendix c.

NEW CLIPPER

category	sample name	bulk density	H_2O content
Control	1-A	1.52	1.0%
	-B	1.58	1.9
	-C	1.71	2.5
	2-A	1.51	1.0
	-B	1.66	2.1
	-C	1.66	2.6
	3-A	1.58	1.4
	-B	1.66	2.9
	-C	1.66	2.2
	4-A	1.62	1.1
	-B	1.60	2.3
	-C	1.57	2.6
	5-A	1.47	1.3
	-B	1.62	2.2
	-C	1.72	2.5
	6-A	1.48	1.3
	-B	1.56	2.6
	-C	1.54	2.8
	7-A	1.54	0.8
	-B	1.57	2.2
	-C	1.54	2.3
	8-A	1.65	0.8
	-B	1.65	1.5
	-C	1.58	2.4
	9-A	1.48	1.2
	-B	1.51	1.8
	-C	1.50	3.0
	10-A	1.49	0.9
	-B	1.53	2.4
	-C	1.39	2.9
Tent Site	24-A	1.60	1.5
	-B	1.56	2.2
	-C	1.63	2.6
	25-A	1.60	1.3
	-B	1.60	2.0
	-C	1.68	1.9
	26-A	1.58	1.4
	-B	1.64	1.9
	-C	1.66	2.2
	27-A	1.65	1.8
	-B	1.49	2.4
	-C	1.59	2.6
	28-A	1.73	0.9
	-B	1.69	3.5

NEW CLIPPER, PAGE II

	-C	1.49	6.0
	29-A	1.52	2.8
	-B	1.57	3.6
	-C	1.43	5.6
	30-A	1.63	3.1
	-B	1.44	5.4
	-C	1.58	4.6
	31-A	1.66	1.8
	-B	1.60	2.9
	-C	1.65	3.1
	32-A	1.66	1.4
	-B	1.64	2.0
	-C	1.68	2.3
	33-A	1.56	1.6
	-B	1.59	2.5
	-C	1.69	2.9
Tent Road	34-A	1.69	2.3
	-B	1.58	3.7
	-C	1.59	3.7
	35-A	1.69	1.3
	-B	1.66	1.9
	-C	1.68	2.3
	36-A	1.52	2.5
	-B	1.54	4.0
	-C	1.50	5.1
	37-A	1.68	1.4
	-B	1.65	1.9
	-C	1.70	2.4
	38-A	1.70	1.5
	-B	1.65	3.1
	-C	1.61	4.0
	39-A	1.72	1.3
	-B	1.57	1.8
	-C	1.67	2.1
	40-A	1.66	1.5
	-B	1.61	1.4
	-C	1.67	2.0
	41-A	1.62	1.2
	-B	1.55	1.9
	-C	1.61	2.3
	42-A	1.72	0.7
	-B	1.61	0.7
	-C	1.65	2.2
	43-A	1.72	1.4
	-B	1.66	1.5
	-C	1.74	1.3
Parking Lot	44-A	1.62	2.8
	-B	1.52	5.7
	-C	1.39	6.4
	45-A	1.53	2.6
	-B	1.53	4.8

NEW CLIPPER, PAGE III

	-C	1.40	7.3
	46-A	1.64	1.3
	-B	1.67	2.2
	-C	1.56	2.9
	47-A	1.61	1.2
	-B	1.55	2.4
	-C	1.61	2.3
	48-A	1.60	1.4
	-B	1.52	4.9
	-C	1.67	2.6
	49-A	1.60	1.7
	-B	1.63	2.5
	-C	1.66	2.4
	50-A	1.66	1.6
	-B	1.57	2.4
	-C	1.63	2.3
	51-A	1.59	1.8
	-B	1.53	2.6
	-C	1.60	2.7
	52-A	1.56	1.3
	-B	1.61	2.3
	-C	1.51	3.4
	53-A	1.62	1.4
	-B	1.54	2.6
	-C	1.49	3.4
Road	11-A	1.86	1.5
	-B	1.97	2.1
	-C	1.88	1.5
	12-A	1.85	0.9
	-B	1.95	1.6
	-C	1.84	1.6
	13-A	1.89	0.9
	-B	1.93	1.3
	-C	1.85	1.5
	14-A	1.77	1.5
	-B	1.83	2.0
	-C	1.80	1.6
	15-A	1.78	1.3
	-B	1.78	2.5
	-C	1.55	2.7
	16-A	1.81	1.0
	-B	1.74	2.3
	-C	1.70	2.8
	17-A	1.86	1.5
	-B	1.83	2.3
	-C	1.83	1.9
	18-A	1.65	1.5
	-B	1.82	2.1
	-C	1.75	1.8
	19-A	1.74	1.2

appendix d.

IRON MOUNTAIN

category	sample name	bulk density	H_2O content
Control	1-A	1.73	0.4%
	-B	1.75	0.3
	-C	1.76	0.5
	2-A	1.67	0.4
	-B	1.79	0.3
	-C	1.68	0.4
	3-A	1.59	0.5
	-B	1.73	0.5
	-C	1.80	0.5
	4 -A	1.66	0.4
	-B	1.68	0.4
	-C	1.81	0.4
	5-A	1.71	0.3
	-B	1.61	0.5
	-C	1.71	0.9
	6-A	1.66	0.4
	-B	1.69	0.4
	-C	1.63	0.8
	7-A	1.68	0.4
	-B	1.74	0.3
	-C	1.77	0.8
	8-A	1.70	0.3
	-B	1.67	0.4
	-C	1.75	0.6
	9-A	1.55	1.5
	-B	1.63	0.7
	-C	1.73	0.6
	10-A	1.57	0.4
	-B	1.72	0.4
	-C	1.75	0.4
Tent Site	21-A	1.84	0.1
	-B	1.86	0.2
	-C	1.74	0.7
	22-A	1.71	0.8
	-B	1.64	0.8
	-C	1.76	0.1
	23-A	1.75	0.2
	-B	1.72	0.2
	-C	1.70	0.3
	24-A	1.82	0.2
	-B	1.73	0.2
	-C	1.76	0.4
	25-A	1.79	0.3
	-B	1.71	0.5

appendix

IRON MOUNTAIN, PAGE II

	-C	1.78	0.5
	26-A	1.79	0.2
	-B	1.74	0.6
	-C	1.77	0.9
	COMP 27	2.00	0.3
	27-A	1.71	0.2
	-B	1.80	0.3
	-C	1.78	0.6
	28-A	1.66	0.6
	-B	1.76	0.2
	-C	1.68	0.1
	29-A	1.78	0.2
	-B	1.71	0.3
	-C	1.69	0.6
	30-A	1.73	0.3
	-B	1.72	0.2
	-C	1.69	0.6
Tent Road	31-A	1.89	0.3
	-B	1.89	0.3
	-C	1.77	0.7
	32-A	1.81	0.3
	-B	1.85	0.3
	-C	1.74	0.5
	33-A	1.80	0.2
	-B	1.71	0.3
	-C	1.74	0.4
	34-A	1.89	0.4
	-B	1.85	0.5
	-C	1.78	1.3
	35-A	1.92	0.3
	-B	1.88	0.6
	-C	1.76	1.3
	36-A	1.83	0.4
	-B	1.93	1.0
	-C	1.75	1.6
	37-A	1.93	0.5
	-B	1.90	0.8
	-C	1.74	1.9
	38-A	1.69	0.8
	-B	1.82	0.6
	-C	1.73	1.0
	39-A	1.97	0.4
	-B	1.82	0.4
	-C	1.77	1.1
	40-A	1.82	0.4
	-B	1.86	0.4
	-C	1.71	0.4
Parking Lot	44-A	1.86	0.3
	-B	1.83	0.4
	-C	1.75	0.6

appendix

NEW CLIPPER, PAGE IIII

-B	1.92	2.4
20-A	1.78	4.0
-B	1.74	2.5
-C	1.64	2.2

IRON MOUNTAIN, PAGE III

	45-A	1.84	0.3
	-B	1.89	0.6
	-C	1.79	1.3
	46-A	1.78	0.3
	-B	1.86	0.4
	-C	1.73	0.5
	47-A	1.76	0.3
	-B	1.84	0.4
	-C	1.70	0.6
	48-A	1.82	0.4
	-B	1.86	0.3
	-C	1.71	0.5
	49-A	1.86	0.4
	-B	1.72	0.2
	-C	1.70	0.4
	50-A	1.89	0.3
	-B	1.93	0.3
	-C	1.73	0.4
	51-A	1.89	1.3
	-B	1.96	0.5
	-C	1.80	1.1
	52-A	1.85	0.4
	-B	1.85	0.4
	-C	1.77	0.6
	53-A	1.79	0.3
	-B	1.87	0.2
	-C	1.80	0.6
Road	11-A	2.00	0.3
	-B	1.75	1.6
	12-A	1.84	0.4
	-B	1.83	1.0
	-C	1.77	1.0
	13-A	2.00	0.4
	-B	1.85	1.3
	14-A	1.85	0.4
	-B	1.77	0.5
	-C	1.79	1.3
	15-A	1.96	0.3
	-B	1.84	0.4
	-C	1.77	0.6
	16-A	1.96	0.3
	-B	1.94	0.6
	-C	1.73	1.3
	17-A	1.95	0.2
	-B	1.90	0.3
	18-A	1.88	0.1
	-B	1.98	0.3
	-C	1.82	0.5
	19-A	1.92	0.1
	-B	1.91	0.3
	-C	1.86	0.5
	20-A	1.94	0.1
	-B	1.94	0.2
	-C	1.71	2.3

appendix e.

GRANITE

category	sample name	bulk sensity	H_2O content
Control	21-A	1.47	0.7
	-B	1.62	0.5
	-C	1.64	1.0
	22-A	1.58	0.4
	-B	1.67	0.2
	-C	1.60	0.4
	23-A	1.45	0.5
	-B	1.65	0.4
	-C	1.60	0.4
	24-A	1.51	0.6
	-B	1.55	0.6
	-C	1.67	0.6
	25-A	1.58	0.3
	-B	1.70	0.2
	-C	1.65	0.6
	26-A	1.63	1.3
	-B	1.65	0.3
	-C	1.83	0.3
	27-A	1.54	0.1
	-B	1.57	0.5
	-C	1.60	0.3
	28-A	1.57	0.3
	-B	1.69	0.3
	-C	1.57	
	29-A	1.49	0.4
	-B	1.65	0.3
	-C	1.64	0.4
	30-A	1.56	0.4
	-B	1.58	0.4
	-C	1.60	0.4
Tent Site	1-A	1.71	0.3
	-B	1.73	0.2
	-C	1.72	0.3
	2-A	1.63	0.4
	-B	1.77	0.4
	-C	1.71	0.5
	3-A	1.65	0.3
	-B	1.90	0.2
	-C	1.75	0.4
	4-A	1.75	0.2
	-B	1.74	0.3
	-C	1.75	0.4
	5-A	1.69	0.3
	-B	1.70	0.4

-C	1.79	0.9
33-A	1.74	0.3
-B	1.83	0.4
-C	1.80	0.6
34-A	1.85	0.2
-B	1.91	0.5
-C	1.76	0.8
35-A	1.90	0.3
-B	195	0.4
-C	1.77	0.7
36-A	1.99	0.2
-B	1.92	0.7
-C	1.87	0.9
37-A	1.65	0.2
-B	1.82	0.4
-C	1.58	0.4
38-A	1.84	0.1
-B	1.82	0.6
-C	1.76	0.7
39-A	1.79	0.2
-B	1.91	0.3
-C	1.75	0.5
40-A	1.88	0.2
-B	1.91	0.6
-C	1.78	0.8

GRANITE, PAGE II

	-C	1.75	0.4
	6-A	1.57	0.4
	-B	1.68	0.3
	-C	1.71	0.5
	7-A	1.63	0.4
	-B	1.64	0.2
	-C	1.68	0.3
	8-A	1.65	0.3
	-B	1.69	0.3
	-C	1.72	0.4
	9-A	1.64	0.4
	-B	1.68	0.6
	-C	1.72	0.3
	10-A	1.59	0.5
	-B	1.72	0.2
	-C	1.66	0.5
Parking Lot	11-A	1.96	0.3
	-B	1.88	0.3
	-C	1.79	1.0
	12-A	1.89	0.3
	-B	1.82	0.3
	-C	1.78	0.6
	13-A	1.74	0.4
	-B	1.82	0.5
	-C	1.82	0.6
	14-A	1.82	0.4
	-B	1.85	0.4
	-C	1.76	0.9
	15-A	1.78	0.3
	-B	1.85	0.3
	-C	1.79	0.5
	16-A	1.78	0.4
	-B	1.84	0.5
	-C	1.84	0.9
	17-A	1.75	0.5
	-B	1.84	0.5
	-C	1.84	0.6
	18-A	1.91	0.4
	-B	1.89	0.6
	19-A	1.81	0.5
	-B	1.87	0.5
	-C	1.76	1.2
	20-A	1.79	0.3
	-B	1.91	0.2
	-C	1.85	0.4
Road	31-A	1.73	0.3
	-B	1.87	0.5
	-C	1.72	0.6
	32-A	1.77	0.3
	-B	1.79	0.7