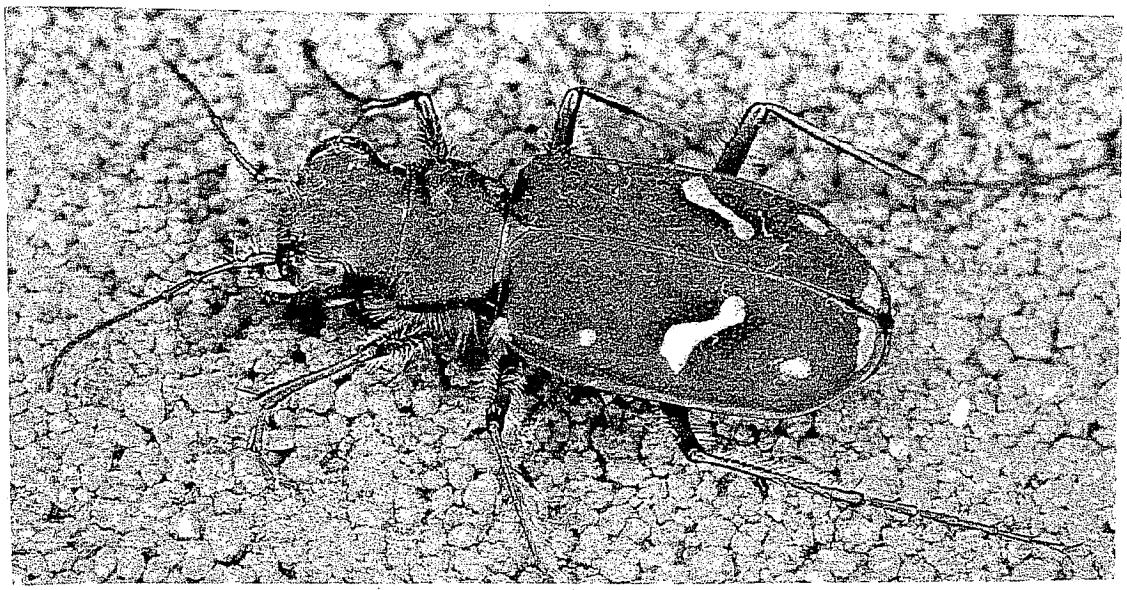
BIOLOGY AND CONSERVATION OF *CICINDELA OHLONE*, THE OHLONE TIGER BEETLE

FINAL REPORT



To: U. S. FISH AND WILDLIFE SERVICE
VENTURA FIELD OFFICE
2493 PORTOLA ROAD, SUITE B
VENTURA, CA 93003

From: C. BARRY KNISLEY
DEPARTMENT OF BIOLOGY
RANDOLPH-MACON COLLEGE
ASHLAND, VA 23005
and
RICHARD A. ARNOLD
ENTOMOLOGICAL CONSULTING SERVICES, LTD.
104 MOUNTAIN VIEW COURT
PLEASANT HILL, CA 94523-2188

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ABSTRACT

1. This report includes results of our studies on the biology and conservation of *C. ohlone* in 2002-2004 along with relevant information obtained by us or others in earlier years. The report attempts to include in one place all that we about this Federally Listed Endangered Species.
2. Our studies focused on the distribution, abundance, and seasonality of adults and larvae; life cycle; habitat characteristics; and recommendations for management.
3. We found the biology of *C. ohlone* to be similar to other tiger beetles. Adults were active on sunny days when temperatures were >16 C. Common daily activities included thermoregulation (basking), foraging, and mating along the trails and trail edtges. Oviposition was observed in the field and in the laboratory. Adults apparently seek shelter in vegetation clumps at night and during cloudy or cool whether, but we did not observe this behavior.
4. *C. ohlone* was reported to occur at maximum of 16 sites, but we found adults and larvae at 9 sites in our surveys in the past three years. Three sites (two Marshall Fields meadows and Moore Creek-Meder) had no adults or larvae and one site (Pogonip) had only a few adults or larvae. Three other sites were privately owned and not accessible. The distribution of these sites includes five separate areas and suggests there may be five populations. Most of our work was at 9 sites where adults and larvae have been consistently present in recent years. Our study did not include searches for *C. ohlone* at new locations, but other workers have previously surveyed over 35 sites. We suggest several areas with potential habitat that should be surveyed.
5. The known sites for *C. ohlone* are coastal terrace grasslands with native species (California oatgrass and needlegrass) but all sites have significant amounts of non-native plants. These invasive species are significantly degrading the habitat by reducing the open bare ground needed by adults and larvae. These sites range in size from 15,000 to 90,000 square meters with an overall total potential habitat of 385,000 square meters combined for all sites (except for ranch sites and sites where beetles not recently found).
6. Peak adult numbers determined from index counts throughout the season varied greatly among sites and years. Sites with the highest numbers (range of 35 to 108 in 2003 and 29-47 in 2004) were at Moore Creek (hereafter MC), Marshall Fields Main Meadow (MFM), Gray Whale section of Wilder State Park (GW) Scotts Valley (SV), and Marshall Fields Back Meadow (MCB). Other sites ((Poliski-Gross (PG), Inclusion Area A of UCSC(IAA), Soquel (Soq)) had smaller numbers, and Pogonip (P) had only a few adults or larvae. Actual numbers at these sites are likely to be at least 2-3 times higher than the index counts, as suggested by a limited mark-recapture study at two sites, and by studies with other tiger beetles comparing index counts with more reliable methods.
7. Both adult and larval numbers at PG and Soq declined significantly in the past two years.
8. The late winter-early spring adult seasonality of *C. ohlone* is apparently unique among U. S. tiger beetles and an apparent adaptive response to the coastal California climate. The range of the adult flight season is from mid-January until early May, but is shorter in a particular year relative to varying climatic conditions. For example, adults were present from very late February to April 22 in 2001, from January 12 to April 13 in 2003 (86 days), and February 2 to April 10 in 2004 (60 days). The short flight season in 2004 was due to extended period of warm days in March. In 2003, warm days in January apparently triggered early emergence

but extended periods of cool, rainy weather caused adults to be inactive and prolonged their flight season. A spring or summer activity period typical of other tiger beetles would be unsuitable for *C. ohlone* because the extreme and prolonged dry conditions during late spring through fall would not permit successful oviposition and early larval development which require soil moisture.

9. Our studies suggest asynchronous development among cohorts of larvae, but a two- year life cycle is probably most common. Some individuals in a cohort or in some years will develop in one year while others may require three years. The typical pattern would be where eggs hatch to first instars during spring and continue in this stage from late spring to early summer (several weeks to a month duration). Second instars are found from summer to early fall (several months duration) while third instars appear by late summer to fall and continue until the next spring and summer, then finally emerge as new adults the third spring (several months to over a year duration) for a two year life cycle in late winter of the third year.
10. Larvae were surveyed by counting and usually marking (with numbered metal tags) their characteristic burrows which we found by searches along the adult survey route. The three larval instars are distinguished by different burrow diameters. Numbers of larvae counted in 2002, 2003 and 2004 were generally correlated with but higher than adults at various sites. For example, highest larval numbers were found at MFF, MFB, GW, MC and SV. SV was unusual among the sites in having very high larval numbers (>500) in 2003 and 2004.
11. Both adults and larvae were distributed primarily along the trails and trail edges at each site, , but bare patches of interior habitat were present at some sites. MFB, GW, and MC were sites that had significant numbers of larvae in interior areas while PG and Soq had few or none.
12. Our monitoring of a cohort of 180 oviposition burrows found survivorship decreased to 62% by May when most larvae were second instars, to 27% by September when most individuals were third instars, and to 9.4% the following spring when 11 individuals emerged as adults (one year life cycle) and 6 continued as third instars (two year life cycle).
13. The results of the study of habitat characteristics indicated that all sites are characterized by high vegetation cover (>90%) and few open bare patches, except for the trails and trail edges. MFB, MC, and GW had significantly less vegetation cover and more bare patches (>25 sq. cm.) than other sites, and this is a probable explanation for more adults and larvae in the interior of these sites. Soq and PG had significantly less vegetation cover, fewer bare patches and very few interior larvae.
14. All sites had one or several disturbance factors that created or kept open the trails and interior open patches. Mountain bikes were the primary factors keeping open trails at MFM, MFB, GW, and IAA; cattle were the key factor at PG and MC; pedestrian foot traffic was the factor at Soquel and Pogonip, and horses were most important at SV. The primary disturbance factors creating open interior areas were pigs (scraping) at MFB, MFB, and GW; gophers and cattle at MC, and ground squirrels at SV.
15. Measurements of several presumed important habitat parameters in three microhabitats (trail, trail edge, interior) at each site demonstrated that trails at all sites were highest in compaction (psi), lowest in % vegetation cover, highest in numbers of 25 sq. cm. open patches at all sites. The trail edges were lower in compaction, higher in vegetation cover and open patches, while the interior had the highest vegetation cover, fewest open patches and lowest compaction. Sites where trails seemed less heavily used had lower compaction levels. Soil moisture (in March) was consistently high (>80%) and not significantly different among sites. Numbers of larvae were lowest in the interior at all sites except MFB (in all 3 years) and at MC and SV in one year. These results suggest larvae are most common in open areas (trail, trail edges, interior) unless the soil there is too compacted.
16. In addition to the above impacts, we found evidence of adult beetles being killed by mountain bike runovers (10 in March 2002 and several in 2003 and 2004) at MFM and GW. We also

observed cases of reduced oviposition or larval mortality at several sites (PGGW) which believe was a result of cattle trampling along the trails

17. A pilot study of scraping surface vegetation from 1 meter square patches demonstrated that adults would readily move to these patches and oviposit in them. First instar larval burrows were also found and some progressed to the second or third stage.
18. A laboratory study to test the possibility of captive rearing, fecundity and the effects of food levels on larval development indicated *C. ohlone* could be reared successfully in the lab. Lab reared adult females produced a highly variable number of eggs (2 to 62) over a four week period, but a probable mean under optimum conditions is probably 40 or more per female. Larval development from first instar to plugging by mature third instars was 109 days for a high feeding group and 161 days for a low feeding group.
19. Management, recovery and additional research recommendations include: protection and management of all present sites to increase population sizes, search for new sites, determination of best methods for improving habitat, and additional research to determine actual population size, patterns of dispersal, and specific soil and other habitat indicators.
20. Finally, the last section of this report includes a summary of characteristics of each site and specific management recommendations for those sites.

INTRODUCTION

This report provides a thorough account of the biology and conservation of the Ohlone Tiger Beetle, *Cicindela ohlone,* including a review of previous work (primarily survey results) by others and work by us in the past three years on the distribution and abundance, life history, ecology, and conservation. The Ohlone Tiger Beetle, *Cicindela ohlone,* is the most recent of 5 tiger beetle species listed as endangered, threatened, or candidates. It was listed as Endangered on October 3, 2001, because of its very limited distribution and abundance, and significant threats to the few, small existing populations. The other listed species include 2 Threatened species, the Northeastern Beach Tiger Beetle (*Cicindela dorsalis dorsalis)* and the Puritan Tiger Beetle (*C. puritana)* and two candidate species, the Coral Pink Sand Dunes Tiger Beetle (*Cicindela albissima*) and the Highlands Tiger Beetle *(Cicindela highlandensis).* The Ohlone Tiger Beetle is found at fewer sites than all of these species except the Coral Pink Tiger Beetle which occurs at only 1 site, but total numbers for *C. ohlone* are probably lower than the others. The Salt Creek Tiger Beetle, *C. nevadica lincolniana,* has been proposed for emergency listing as endangered. The Sacramento Valley Tiger Beetle, *C. hirticollis abrupta,* was very recently petitioned for listing as endangered. There are 10 or more other U. S. tiger beetle species that are probably comparable in rarity, but not yet listed.

Cicindela ohlone was described by Kavanaugh *et al.* (1993) from several remnant grassland sites in Santa Cruz County, CA. These workers reported it was similar in taxonomy and morphology to *Cicindela purpurea,* but clearly distinguished by several morphological characters, its separate geographic range, and a different life cycle. Most of the known information on this species is included in the above paper and in the proposed ruling in the Federal Register (2001). Additional information on the species is found in numerous unpublished reports and field notes of various workers, and some of that is included in this report.

The specific objectives of our study were to:

1. determine current distribution and abundance of adult and larval numbers within each of the known sites.
2. determine seasonal activity and life cycle
3. measure selected habitat factors that might explain distribution and abundance or be threats to the species
4. conduct laboratory rearing studies to determine fecundity and effects of food levels on larval development and the potential for captive breeding of this species
5. make recommendations for management and recovery

METHODS

Adult Abundance and Distribution. Our studies did not involve a search of new locations for *C. ohlone*, but we do include (in the appendix) tables of results by Hayes, Morgan and others who surveyed many coastal terrace prairie sites in Santa Cruz, San Mateo and Monterrey Counties. We include topographic maps of these survey sites. Our studies were concentrated primarily at 9 of the 16 sites where the OTB has reportedly been found. Three sites were not surveyed because they are privately owned. We found no beetles at three other sites. We do not include in this report the results of earlier surveys (1987-2001) by various workers since these often represented only a single count in only a portion of the site and may not have been in peak season or under ideal conditions.

In 2003 and 2004 we conducted surveys at eight sites every 1-2 weeks throughout the adult flight season (late January through April). Other sites which had few or no adults were also surveyed several times each year. Our primary method for estimating adults numbers was the use of visual index count (Knisley and Schultz 1997) on the primary trails or paths at each site. The trails and paths were used because previous experience indicated this is where most adults were found and where they could be easily seen and counted. We followed the same survey route on each survey date in both years. The method was to walk slowly along the established routes and search the ground 3-6 m ahead so the beetles could be seen and counted before they flew up. When beetles were seen we usually detoured off the trail to avoid disturbing them. For each single adult or small numbers of adults within 2-4 meter of each other, we recorded the specific location (latitude/longitude) using a Garmin Legend or Vista GPS unit. These locations for each date and at each site were used to produce a GIS map of the areas of the habitat occupied by adults. Air temperatures were also recorded at the start of each survey. Our surveys were usually done on warm, sunny days when we knew adult activity would be optimum, but intermittent cloudiness and daily temperature variations accounted for some of the variation in the numbers counted (see below). On some days we also searched areas of interior habitat off of the trails to determine the extent to which adults may be using in these areas.

It should be noted that these index counts may be adequate for comparing abundance among sites and over time, but as some studies (including Gowan and Knisley 2001) have demonstrated, they may not provide an accurate estimate of population size. For the OTB as for

other tiger beetles this method usually significantly underestimates adult population size. The underestimate results from missing some adults that fly off out of view before being counted and others that are hiding in denser vegetation or otherwise inactive during the counts. For our surveys, this method also did not account for beetles in areas of interior habitat not thoroughly surveyed. To obtain some indication of the relationship between an index count and actual population size, we conducted a 4-day pilot study comparing daily index counts with mark-recapture estimates at two sites during the peak flight season in March 2002. During our frequent site visits for the surveys we compiled a considerable amount of observational information on beetle activity, feeding and oviposition behavior, and potential prey organisms.

Larval Surveys and Life Cycle. Field surveys to obtain information on distribution, abundance, and development times of larvae were conducted from 2001 to 2004. Our surveys for larvae were similar to adults in that we searched the same adult survey routes but shortened our search distance to 1-2 meters and progressed much more slowly to find evidence of the characteristic larval burrows. The trail edge was also thoroughly checked for burrows since many were there. Open areas of the interior habitat beyond the trails were less intensively searched. Larval burrows of tiger beetles are recognized by their round to very slightly oval shape and distinct smooth even perimeters and a depth of > 6 cms. The burrows or holes caused by other invertebrates usually have ragged or uneven margins or are more shallow. However, burrows of some ground nesting bees co-occur with larvae at some sites, and are very difficult to distinguish from larval burrows. First, second and third instar larvae can be distinguished by burrow diameters (1.5 to 6 mm) which occurred in distinct size classes (reported in results along with burrow depths). When larvae are alive and active their burrows are typically open. When burrows are plugged the larvae may be dead, in the process of molting to the next stage, or in a period of prolonged inactivity (Knisley and Schultz 1997). Eroded burrow probably indicate the larvae are dead. In some years we were also able to find and mark adult oviposition burrows. These were smaller in diameter than first instar larvae and most easily found when the soil was wet. At most sites we marked larval burrows with round metal tags (Forestry Suppliers, Inc.) attached to the ground surface with a nail so we could obtain accurate counts and monitor development and survival of larvae over time. Specific burrow locations were recorded with a GPS unit and the locations for each burrow used to produce a GIS map from which we could determine the distribution and density patterns for larvae at each site. Useful data was lost because of vandalism or loss of tags at some sites.

The most complete data set on larval development and survivorship was obtained by marking adult oviposition burrows at one site (PG) when they first appeared in March of 2001. We rechecked these marked burrows at least once per week until June and at least once per month until the following spring to determine larval activity, survival, and stage of development.

Habitat Characteristics and Disturbance Factors. At all of the sites except the private ranches we determined the amount of potential OTB grassland habitat by recording the perimeter of the habitat with a GPS unit. The trail lengths of our survey routes at each site were also measured. At each of the primary survey sites in March 2003 we measured a series of habitat parameters that we believed might affect the distribution and abundance of adults and larvae. These parameters included percent cover of vegetation, number of bare, unvegetated patches

(>25 sq. cms), soil moisture, soil compaction and animal disturbances in three separate microhabitats (trail, trail edge, interior habitat). The survey design for obtaining these measurements involved establishing a transect along the trails or paths that were the same as the adult and larval survey route at each site and from this main transect extend a series of 50 to 100 meter cross transects perpendicular to the main transect at 25 to 50 meter intervals. At sites where the trail was not centrally located the cross transect extended from only side of the trail to the interior habitat. Since the sites were similar in size and configuration, we predetermined our sampling design to include an equal number of survey points along the transects for collecting data by adjusting the survey intervals along the main and cross transects. Overall average values for the habitat parameters were calculated from the series of measurements taken at the survey points for the trail, edge and interior at each site. Total percent plant cover was estimated using a 1-meter square frame (subdivided into 25 sq. cm sections) placed at 25 to 50 meters intervals along the center of the trail and the adjacent trail edge and at the same intervals for 50 to 100 m on the cross transects. In addition to the total percent cover, we also obtained a measure of open patches by recording the number of 25-sq. cm sections in the frame that had no vegetation. Soil moisture was determined using an Aquaterr (Fremont, CA) soil moisture meter which gives a relative index of moisture (0 to 100). We recorded the average from three readings taken within each of the 1 meter frame survey points. Soil compaction was measured in psi using a Dickey-john soil compaction tester (Spectrum Technologies, Inc., Plainfield, IL). As with soil moisture, we recorded the average of three readings within each the 1-meter frame at each transect survey points. From these we calculated mean values for each of the three microhabitats at each site.

In April 2004, we repeated the measurements of vegetation cover (as above) along with vegetation height and the number of animal disturbances. These disturbances include scrapings from wild pigs, soil piles and bare areas from gophers, bare or sparsely vegetated patches caused by ground squirrel burrows and trails, and trampled bare patches from cattle. These parameters were determined along 50 to 100 meter cross transects extending perpendicular from the main transect at each site. Vegetation cover was measured using a 1-meter square frame placed at 40 survey points along the cross transects at each site. To quantify animal disturbances we counted the total number of separate disturbance patches found within 1 meter of either side for a total 500 meter length (20 25-meter transects at most sites) of the cross transects. The cross transect layout with varying intervals and length was pre-established at each site to have an equal number of survey points and transect lengths so we could compare these factors among the different sites. This method, however, did not account for differences in sizes of the patches. Other habitat disturbances from pedestrian foot traffic, cattle grazing or mountain bike usage were not quantified, but we do include anecdotal information on some of the factors.

Habitat Scraping. In order to determine if we might be able to enhance or increase habitat, especially for oviposition, we conducted a pilot experiment of vegetation removal at one site (PG). We used shovels to scrap away the top 3-6 cms of soil (with vegetation) from a series of approximately 1 meter square patches in March of 2001 and 2002. The patches were 15-25 meters apart and parallel to and 10-30 meters from the trail that ran through the site. These scrapped patches were subsequently checked for the presence of adults, evidence of oviposition (oviposition burrows), larval burrows, and vegetation growth 1-2 times per week for about six weeks.

Laboratory Studies. In order to test the potential for laboratory rearing and to obtain information on adult fecundity, life span and the length of larval stages we conducted laboratory rearing studies using methods previously described (Pearson and Knisley 1985, Knisley and Schultz 1997). Because of the rarity of the species we initiated these studies with only small numbers of adults (10 females, 3 males) that were field collected on 3 different dates in March 2001. The females were confined alone or with a male in small plastic terraria (24 cm long x 12 cm wide x 15 cm high) with a 10-cm layer of sandy-clay soil and covered by a screen top. Water was added on alternate days to provide soil that varied from well saturated to surface drying. Food was provided *ad libidum* by placing 10-15 *Tribolium* (mixed adults and larvae) into the chambers each day. The terraria were kept in a controlled temperature chamber at 25-27 C. for the duration of the studies. So that fecundity could be determined over the life span of adults, the beetles were transferred to new chambers every 7 days. Watering of these chambers was continued after adults were removed and were checked daily for the presence of first instar larvae. When all of the larvae in a chamber had hatched (within 15 days after adults were removed), we emptied the soil from the chamber into an enamel pan and examined the soil for the presence of eggs or first instar larvae. These larvae were transferred to individual 2 cm diameter x 12 cm long acryllic tubes filled with habitat soil that was saturated with water and stopped at one end with a foam plug (Knisley and Schultz 1997). The larvae were placed on top of the damp soil and rapidly dug burrows.

To assess effects of food level on rate of larval development and to reflect possible variations in feeding levels that larvae may experience in the field we provided larvae with one of two food amounts. The first instars in one (low food) group were provided with 1 small *Tribolium* larva (0.5 mm) every two-three days; second instars were fed 1 medium *Tribolium* larvae (0.7mm) at the same interval; and third instars were fed 1 large *Tribolium* larva (>1.0mm) at the same interval. The other (high food) group was given one of the same-sized *Tribolium* per day. From daily checks of each larval rearing tube we determined for each instar the numbers of days from the beginning of a stage to the time the larva plugged its burrow prior to molting to the next stage and length of time before re-opening its burrow and emerging as the next stage. Most of the larvae progressed only to the third instar and became inactive in this stage, did not feed or complete development to pupation.

RESULTS AND DISCUSSION

Biology. We found that adults of *C. ohlone* were typically active from mid-February through April (see more below) on sunny or partly sunny days when air temperatures were near or above 16 C during their flight season. They were not found during cloudy days at the same temperatures or on sunny days when temperatures were much lower than 16 C. We most often found the adults thermoregulating (basking), foraging or mating on bare ground of trails or sparsely vegetated trail edges. We did not determine what adults do during the frequent periods of cloudy cool weather during the day and at night, but like related species in similar habitats they probably crawl into patches of dense vegetation until conditions improve. Some tiger beetles, including the closely related *C. purpurea,* may dig burrows to escape these unfavorable conditions, but that is unlikely by *C.ohlone* because the soil is too hard. The mating pairs that

we observed often remained attached without copulation for prolonged periods (15 or more minutes), possibly indicating contact guarding as reported for other tiger beetles (Kraus and Lederhouse 1983). This behavior apparently functions to prevent other males from mating with the female. It involves the male grasping the female with its mandibles, but does not mate. We observed over 20 instances of adult feeding, mostly on small black spiders and ants that were common at the field sites. On some occasions we observed adults attack and reject these small black spiders. Oviposition was observed both in the laboratory and in the field. It was typical of that reported for other tiger beetles and lasted 5-15 minutes. In the field, the female positioned herself nearly perpendicular to the ground and pressed the extended ovipositor (at the tip of the abdomen) into the soil to deposit an egg 1-2 cms below the surface. We recovered eggs from several of these burrows. Several females ovipositing in the laboratory chambers used the ovipositor to dig the oviposition burrow by removing soil particles before placing the egg. These excavated particles were found commonly in the laboratory chambers (also sometimes in the field). Digging may occur only when the soil is harder or drier and the egg cannot otherwise be placed suitably. The egg sizes of several of those measured in the laboratory were 1.5-1.8 mm diameter x 2.5-2.8 long. Adult females will probably only oviposit when the soil is moist at or just below the surface. Tiger beetle females will place only one egg in each oviposition burrow, then move to other locations (nearby) to deposit other eggs. In the field we occasionally found clusters of 3-8 oviposition burrows within a several square cms area. Shelford (1909) found that some oviposition burrows did not have eggs in them so burrow numbers cannot be used to estimate fecundity.

Adult Distribution and Abundance (Where Does the OTB Presently Occur and How Many Are There?) The most complete surveys to determine the geographic range of the OTB were done in the 1990's, and focused on coastal terrace grasslands, the habitat type where the species was found. The results of those surveys, included in the petitions submitted to USFWS in 1993 and 1997, indicated *C. ohlone* was limited to only a few sites in Santa Cruz County. Morgan (1993) surveyed 16 sites in Santa Cruz County, most near existing sites, but found the OTB absent from all of them. Additional surveys by Hayes and others from March 8 to April 21, 1995, confirmed the absence of *C. ohlone* at 20 of 21 other coastal terrace grassland sites in Santa Cruz, Monterey, and San Mateo Counties, even though all had some potential habitat (Hayes 1997). That survey did identify one new site with very few adults (Pogonip). All potential habitat at Wilder State Park was surveyed by Tim Hyland in 2002 and 2004 (see appendix) but no new OTB sites were found. These survey results are probably indicative of the rarity and habitat specificity of the OTB, but because this and other tiger beetles species may occur in small numbers in limited areas of habitat, and are often difficult to spot in the more heavily vegetated areas, additional survey work at some of these and other unchecked areas should be conducted. The most important of the new areas to check (according to G. Hayes who has studied coastal terrace prairies) are: much of the Coast Dairies property, especially that between W. Lydell and Laguna Creek and other areas north of Davenport (east between Davenport and Davenport Landing), meadows north of Paradise Park (horse track area, Felton quad), DeLaveaga Park (northeast of parking lot, Frisbie golf course), the Graham Hill area, and Butano State Park. These sites have some of appropriate habitat characteristics and soil type and may be suitable if not too densely vegetated.

The results of our surveys and those of other workers indicate that *C. ohlone* has been found at a total of 16 sites, all in Santa Cruz County (Fig. 1, Table 1). Our research in the past three years found that 8 sites have had a consistent presence of OTBs, one site has had only a few individuals in one of three years, and four sites have had no adults or larvae. The three other sites where adults were previously found are private ranch sites were not accessible to us. The current status of populations there is unknown. The number of actual OTB populations, is uncertain since we have no information about dispersal or exchange of adults among the sites. Figure 1 indicates the 16 sites occur in five somewhat separate areas and suggests the possibility of five distinct populations. These are; 1. Soquel; 2. Scotts Valley; 3. Pogonip (but currently not a viable population); 4. Moore Creek, Poliski-Gross, Inclusion Area A, Private Ranches; and 5. Gray Whale, Marshall Fields, UCSC Natural Area. Studies with tiger beetles indicate most species have good dispersal ability, and may often move several kilometers or more.

Details of the characteristics of the individual OTB sites are discussed later in the report, but we give here an overview of the adult numbers and important site characteristics. Previous workers have reported that *C. ohlone* occurs in coastal terrace grasslands, mostly dominated by two native species (California oatgrass and needle grass) (Kavanaugh *et al.* 1993). These sites also have significant representation or dominance of invasive grasses and herbs which have reduced the quality of these habitats. All of the known OTB sites are relatively small and thus have a limited amount of potential habitat for the adults and larvae (Table 1). Potential grassland habitat at these sites ranges from approximately 4000 to 90,000 sq. meters with a total area of 555,000 sq. meters for all sites combined. This estimate includes the 16 known sites including the sites where beetles have recently been found, but the actual area for the private ranch sites were less certain. Our estimate compares with 121 hectares reported as potential habitat by Kavanaugh *et al.* (1993). We have not yet determined the amount of area at each site that is used (actual habitat) but it is likely to be significantly less than the total habitat area we report for each site. Unsuitable habitat for adults and/or larvae at each site includes areas that are very densely vegetated, significantly impacted by man (mountain bikes, gravel on trails), excessively wet or with water logged soils, or thin rocky soils. The primary human impacts we found at each site are briefly characterized in Table 1 (impacts and disturbances discussed later). These OTB sites occur over a significant range of elevations, from less than 100 meters to over 300 meters.

The peak numbers of adults that we found during our index counts in 2002, 2003 and 2004 at all sites, habitat area, elevation, trail length and site impacts (discussed below) are given in Table 1. Table 2 (A and B) provides the most accurate and up-to-date data on adult populations at the OTB sites in 2003 and 2004 throughout the season because the survey methods used and area covered were identical. The surveys suggest that the highest numbers and apparent largest populations are at Moore Creek (MC), Marshall Fields Main Meadow (MFM), Scotts Valley (SV), Grey Whale (GW), and Marshall Fields Back Meadow (MFB). Peak adult numbers at these sites ranged from 35 to 108 in 2003 and from 29 to 47 in 2003. Numbers at all sites except Grey Whale were higher in 2003 than in 2004, and at many sites peak abundance in 2004 was twice as high. Highest counts in 2003 were at MC (108), MFM (78), SV (75), and Poliski-Gross (PG) (53). In 2004 highest counts were at MFM (47), MC (46), SV (39) and GW (38). Lowest counts and apparent lowest population sizes were found at Inclusion Area A (IAA), with 14 in 2003 and 4 in 2004 and Soquel (S), with 23 in 2003 and 7 in 2003. No adults were found at Moore Creek-Meder St. and this population, where 20 adults were counted in the

late 1990's is now apparently extinct. No adults and only a few larvae were found at Pogonip in 2002 and 2003, and only 3 adults in 2004. This population is thus marginal and probably not viable.

The adult densities (see Table 1), determined as numbers of beetles per length of trail surveyed, were generally correlated with adult numbers per site. Highest densities of 20 or more per 100 m of trail were at Scotts Valley (30), Gray Whale (29), Marshall Fields Main Meadow (20) and Marshall Fields Back Meadow (20). However, at all of these sites, the adults were localized at much higher densities (often 5 adults per 10 meters length) within certain sections of the trail. We have not yet completed maps of adult distributions (based on GPS work in 2003) but, in general, adult distributions were similar to the larval distributions which we show with a series of maps included in the appendix of the report.

A comparison of the 2003 and 2004 (and some earlier) counts (Table 2) indicates the significant year-to-year variations in abundance that is common for tiger beetles (and most other insect populations). Causes of these fluctuations cannot be reliably determined but climatic factors are likely to be among the most important of various factors. Our surveys indicate significant declines in numbers at both Soquel and Poliski-Gross in 2004 from 2003 and previous years. At PG adults were relatively abundant in 2002 (index counts near or over 40) and in 2003 (53) but declined to 13 in 2004. Cattle grazing may have had a significant impact by causing disturbance and possible mortality to adults while they were inactive in grass clumps. It is even more likely that cattle had a negative impact on oviposition and larvae at this site (see below), since we found relatively little larval recruitment at this site in 2003 and very small numbers of larvae in 2004. Adult numbers at Soquel declined dramatically early in the 2003 adult flight season (early February) while numbers at all other sites increased. Possible causes are adult loss from collection or mortality or inactivity due to the drying out of the soil. This is the site that is best known to collectors and could be subject to overcollection. Adult numbers were even lower at this site in 2004. Larval numbers were also significantly lower in 2003 and 2004 than in previous years.

It is certain that the index count method we used are an underestimate of the adult numbers as each site. We discuss this in more detail in the discussion section of the paper, but the most significant evidence of this underestimate were the results of a marking study at two sites (PG and Soq) in 2003 when over 150 different adults were marked during a 4-day period and only a few were recaptured. Highest index counts during this same period time were less than 50.

As indicated above, we recorded GPS locations of all adults found at all sites and all dates in 2003. The maps of these distributions have not yet been completed, but the adult distribution was generally similar to that of larvae (describe below). Most adults were on the open areas of the trail and trail edges. Numbers of adults among the open patches of the interior areas varied greatly among sites, and in generally corresponded to the amount of open areas. For example, relatively large numbers of adults were found in bare pig scraped areas at MFB in 2004 (see Table 2). Adults were also common in these areas in 2003 and at interior areas at MC and at GW. We found no interior adults at Soquel and few at most other sites. A survey of adult distribution was conducted at PG in 2001 when numbers were counted within 10 different

sections along the survey route. Cumulative total beetle numbers for 9 survey dates within these sections indicated most adults were along certain trail sections but also in the Mima mound section near the middle portion of the site which was generally well vegetated. numbers were along the primary trail at the site. In 2003 and 2004 we found most adults along the trail and few in the interior areas of the Mima mounds.

Adult Seasonality and Weather. The unique late winter/early spring activity period of adults of the OTB is apparently an adaptation to the seasonal climatic pattern in the central California coastal habitat. No other time of the year would be as suitable for successful oviposition and early larval development (see discussion section below for more detailed explanation). While the daytime highs are often marginal for adult activity, there are enough sunny, warm days to allow adults to thermoregulate and carry out their necessary activities. The 30-year weather records for Santa Cruz, CA indicate this pattern. There is a slight increase in the mean high monthly temperatures from 16 C in December and January to 17 in February and 18 in March when adults emerge and reach peak numbers (Fig. 2). During this period there are an adequate number of sunny or partly sunny days when air temperatures are 16 C or higher, the apparent threshold for OTB adult activity during sunny days, to allow for adult activity. The highest mean rainfall amounts are in the months before (16.5 mm in Jan, 15.6 mm in Feb.) and during the time of peak adult activity in March (12.1 mm). Rainfall declines rapidly in April (5.0 mm) and continues very low through summer and fall. This pattern provides the wet soil needed for oviposition and egg hatch before the extended unfavorable dry conditions begin in late April.

Adults of the OTB emerge in late winter, reach peak numbers and then gradually decline until early to spring when all adults have died off. Collection records and our studies of adults indicate the full span of seasonal adult activity is from January 17 until mid-May (also see petition and Kavanaugh et al. 1993). In the past three years we found that the adult flight season in any one year is usually much shorter in length, and the time of first emergence and peak abundance varies from year to year. Such variations are undoubtedly due to year-to-year weather variations. For example, in 2003 the flight season began early and was short, beginning on January 17 (apparently because of a warm period in mid-January) and continued to April 13 (86 days). In 2004 adults were present only from February 2 until April 10 (60 days). The period of adult presence at individual sites varied slightly within this range. For example, in 2003 adults were found earlier and remained longer at Grey Whale. At PG in 2001, adults emerged shortly before March 5 and were gone after April 22. Typically adults reach peak numbers about 2-3 weeks after first emergence then decline gradually over a several week period until all have died off, leaving a cohort of larvae to develop and subsequently produce new adults.

Adult seasonality and the numbers of adults active on a particular day were significantly affected by temperature and sky conditions. We found that the threshold for adult activity on sunny days was about 16 C. Adult numbers typically increased as temperatures increased from 16 to over 21 C., and they were highest when temperatures were in 19 to 23 C., unless it was later in the season when numbers were declining. Since tiger beetles use behavioral thermoregulation, especially basking, to increase body temperatures, they are inactive on cloudy days, even when temperatures are above 16 C. In the Santa Cruz area there are many such days when adults are inactive during their normal flight season, and even extended periods of cloudy,

cool or rainy conditions there is little or no activity. For example, in 2002 there was such a "lull" in adult activity for two weeks in mid- to late-March. Adults then resumed activity in early April before dying by early May, suggesting that these long periods of inactivity can extend the adult seasonal pattern. Conversely, sustained warm and dry conditions can increase adult activity and reduce their lifespan. This occurred in 2004 when there were unusually warm and dry conditions for several weeks in March which probably caused adults to die off more rapidly.

Larval Studies. Distribution and Abundance, Life Cycle, Development. The burrow diameters and depths for the three larval stages (10-15 for each stage) found in the field surveys were as follows:

First instars: mean diameter of 1.7 (range of 1.5-2.2); mean depth of 4.6. cms .
Second instars: mean diameter of 2.9 (range of 2.4-3.2) and depth of 5.9 cms.
Third instars: mean diameter of 4.6 (range of 3.7 to 5.2) and depth of 8.2 cms.

The mean burrow diameters and depths for lab-reared larvae were 2.48 mm (range of 2.4-2.6) and 5.2 cms for first instars; 3.27 mm (2.8-4.0) and 6.2 for second instars; and 5.6 (4.7-6.3) and 12.3 (10-14) cms for third instars).

The results of the larval counts (including numbers for each instar) at all sites in 2002, 2003, and 2004 and their distribution among three microhabitats (trail, trail edge, interior) are given in Table 3. These are late summer counts (except for 2004) because this is the time when we found the highest level of activity. In spring, many first instars have not yet hatched and second and third instars from the previous cohort have not yet become active. The summer counts, however, would include these but not any first instars or others that did not survive. These larval counts provide only an index of relative abundance because numbers of larvae that are active are affected by many factors (such as climate conditions) and may not be comparable among sites and years. The proportions in the different larval instars also varied, with few first instars found at this time in 2003 compared to 2002. In general, these larval counts indicate sites with larger adult populations (MFF, MFB, MC, GW and SV) also had highest larval numbers. These sites typically had 50 to over 100 larvae, numbers generally similar to the range of adult numbers at these sites. The apparent population declines at SCG and PG suggested by a decline in adult numbers during the past three years is further supported by the decline in numbers of larvae during this period. Larval numbers at the other sites suggest more stable populations, except at SV where larval numbers were unusually high compared to adult numbers in 2003 and 2004. The numbers of third instars in 2003 (434) and in 2004 (274) were much higher than we have found at any other sites and unexpected since the adult numbers in 2001 and 2002 which produced these larvae were not significantly higher than other sites. This suggests that conditions for recruitment and larval survival were exceptionally favorable. (We did not survey larvae at this site in 2001 and 2002).

As indicated in Table 3, larvae (larval burrows) occurred in all three of the microhabitats surveyed, but varied considerably among these three and among sites and years. At most sites burrow numbers on trails were low, except at several sites where these trails were less heavily compacted (MF and Soq). There was great variation in the numbers of larvae in interior areas, among sites, primarily due to the amount of open, unvegetated habitat in these microhabitats.

The interior microhabitat at MFB, MC, and GW, which had lower vegetation cover and with more open bare patches had large numbers of larvae. Soq, PG, and MFF had very few interior larvae and also very high interior vegetation cover. We discuss the factors influencing larval distribution below in the habitat section.

Larval development of *C. ohlone*, like that of other tiger beetles includes three instars and is greatly influenced by various factors, especially food and climatic, which alter the rate of larval development (see discussion section for more details). There is also considerable asynchrony within a cohort and commonly producing a year difference in development time. Our monitoring of marked larval burrows and surveys of larval numbers and stages at various sites indicate the life cycle of OTB ranges from one to three years, but most individuals of a cohort progress from adult to adult in two years. The most common pattern is as follows. Adults emerge and oviposit during their mid-February to early April activity period. The first instars hatch and remain in this stage from late spring until early summer, then progress to the second instar which is usually found from late spring to early summer. Progress to the third instar stage may occur during summer or be delayed by until the following spring. In most years we have found that most third instar larvae are inactive and with plugged burrows from early fall until mid-March to early April of the following year. These third instars complete development during the second spring and summer and emerge as new adults in the following year, thus completing a two-year life cycle. Development from egg to adult may be completed in one year if oviposition and hatch occurs early, adequate food and climatic conditions exist, but late emergence, limited food and unfavorable conditions may result in three years for development of some individuals.

The fate of the 180 oviposition burrows marked in March 2001 is given in Table 4 and Figure 5. The development of larvae in this cohort was more rapid than we found in some other years, with most individuals apparently completing development in one year. First instars seen in April and May progressed to the third instar by July to September. In spring of 2002, 11 of the 35 third instars from September emerged as new adults while 6 continued at third instars, and would not complete development until the following year (a two year life cycle). Data from larvae in other years indicated most required two years, and some three years to complete development. Our monitoring of this cohort in 2001 provided us with information of survivorship (Table 4, Figure 4). From these 180 oviposition burrows we found 112 or 62 % survived to the first or early second instar by May. Survivorship declined significantly and progressively and by September only 27% of the cohort was alive. Among these 49 survivors were no first instars, 12 second instars, and 35 third instars. This distribution of stages indicated the typical variation on development progress with a cohort and that most larvae had developed to the third stage. From September until the following spring, survivorship declined to 9.4% (17 survivors) with 11 individuals emerging as adults and 6 continuing as third instar larvae for another year. Similar data from marked larvae at other sites and in other years indicated a two-year developmental pattern was more common the one-year life cycle at PG in 2001.

Habitat Characteristics, Disturbance Factors, and Their Effects on the OTB.

The results of our vegetation measurements indicate all sites to be high in vegetation cover and with few bare patches of open soil. There was significant variation among the sites, however. In the April 2004 habitat study, mean percent vegetation cover in the habitat interior

was high and over 92% at all sites, but significantly lower at Marshall Fields Back Meadow, Moore Creek, and Gray Whale (Table 5). These three sites also had more 25 sq. cm bare patches (16 and 21, respectively) than other sites. Soquel, Pogonip, Scotts Valley, Poliski-Gross, and UCSC Inclusion Area A had the highest percent interior vegetation cover, over 98% at each, and the fewest the open patches. Mean vegetation height ranged from 15 to 33 cms and was a probable negative impact factor for adults and larvae at all sites. Soq and P had the highest mean vegetation. All sites had one or more disturbance factors responsible for creating or maintaining the bare trails and open bare patches in the habitat interior. The primary disturbances keeping the trails open were: mountain bikes at MFM, MFB, GW, and IAA; cattle at MC and PG; horses and pedestrian foot traffic at SV; and pedestrian foot traffic at Soq and P. These and other disturbance factors were responsible for creating the open patches in the habitat interior. Scraping from wild pigs, found only at Marshall Fields (MFF and MFB) and GW, was responsible for creating the largest and most numerous open interior bare patches. Gopher diggings, indicated by piles of loose dirt were common at most sites, but most abundant at MC, MF, Soql, and IAA. These dirt piles were usually transitory accumulations of loose soil which were often not suitable for larval burrows for long enough for them to complete development. Some of the gopher dirt piles at MC and GW were more compacted and extensive and more suitable as oviposition or larval habitat. Cattle trampling was the most important factor in creating bare trails at PG and MC, but also created some additional open interior patches from grazing and trampling at these sites. A large population of ground squirrels at SV produced bare patches around burrows and runways. We found these areas used by adults and also supported very large numbers of larval burrows.

The March 2003 habitat study (Table 5) compared vegetation cover and other habitat factors in three microhabitats (trail, trail edge, interior) since we also counted larval burrow numbers in these microhabitats. As expected, the trail was the only microhabitat with a high amount of unvegetated ground surface (usually 40% or less cover). Vegetation cover for the edge microhabitat ranged 78 to 95% while the interior microhabitat was 83% or higher at all sites. The interior percent vegetation cover was significantly lower in the 2003 study compared to 2004 even though the same methods were used. The differences were probably because the 2004 surveys were over a month later and vegetation growth had progressed much further than in early March 2003.

Soil moisture, measured in early April 2003, was high (>80%) and not significantly different among the three microhabitats (trail, trail edge, interior) at any of the individual sites. There were mean differences among the sites but none were significant. These results and our observations indicate soils are consistently very wet during the late winter/spring activity period of adults, and provide ideal conditions for oviposition and early larval development. We also observed that some sections in most habitats had excessively wet areas where water would pool on the surface for extended periods of time during this period. In some sites we also noticed that the soil surface will sometimes dry during this period if there is no rain for a week or more. But the soil below the surface where larval burrows extend remains moist into the summer months.

Soil compaction readings were significantly different among the three microhabitats at all sites (p values of ANOVAs for all sites of <.05) (Table 5). The trails had the highest compaction (means ranging from 177 to 266 psi), edges were lower (86 to 113) and interior sites lowest

(<85). There were notable differences among sites with Scotts Valley, the two Marshall Fields sites and Moore Creek having trail compaction readings significantly less than the other sites ($p<.05$). Edge compaction values were similar among all sites and none significantly different from others. Interior compaction readings were significantly lower at both Marshall Fields sites than at other sites. These differences in compaction probably result from differences in trail use and not to soil type which seems similar at all sites. The causes of the compaction were variable among sites. Mountain bike activity was the main cause of trail compaction at Gray Whale and Marshall Fields sites while cattle grazing was the primary compaction factor at Poliski-Gross and Moore Creek. The primary causes of compaction at Scotts Valley was horse riding and pedestrian foot traffic. Pedestrian foot traffic was the significant factor at Soquel and Pogonip and less important at a number of other sites.

Habitat and Beetle Impacts. Our studies suggest that the primary habitat limiting factor for adults and larvae at all sites is the lack of suitable bare or sparsely vegetated ground. The lack of bare ground is primarily a result of the increased growth of non-native vegetation. Most of the bare ground at all sites is a result of disturbance factors (mountain bikes, cattle grazing, other animals), some of which may simultaneously have positive and negative effects on *C. ohlone* populations. Evidence for a significant direct effect on beetles was the finding of dead or injured, crushed beetles along several of the trails at MF and GW when adult beetle activity coincided with heavy mountain bike use. Ten adults were found during monitoring of two trails on March 10-13, 2002. We also received several additional reports of similar cases of beetles apparently killed by mountain bikes at these sites. The beetles were crushed and/or had split or missing elytra and were almost certainly runover by mountain bikes. Since that time, protective fences have been put in place to restrict mountain bike on these trails use during the adult flight season.

These is also some anecdotal or circumstantial evidence of probable negative impacts from cattle and mountain bikes. We found about 30 of our metal tags used to mark burrows at PG were dislodged by cattle hooves and the soil cut away from around them. Some of these burrows were not re-opened by the larvae, possibly because the larvae were killed. The absence of larvae from several trails heavily used by mountain bikes or cattle where adults were common may be the result of the compacted soil or other effects of these disturbances. For example, at GW larvae have been nearly absent for several years from the main trail which is heavily used by mountain bikers and very compacted. They have been found along the trail edges and also along several less used trails nearby. Larvae were also absent from a heavily used cattle trail at MC in summer 2002 where adults were very common in March 2002. Heavy cattle grazing at PG in March 2002 during peak adult activity may have been the cause of the very small numbers of larvae at this site, especially compared to other sites where fewer adults had been seen. This site also had much higher numbers of larvae in 2001 when cattle grazing did not begin until after the peak adult activity period. Another possible impact of cattle grazing that we could not determine was the trampling of adults during times when they have taken shelter under the vegetation or in shallow burrows during periods of unfavorable weather and at night. We must mention, however, that these disturbances although potentially damaging, also maintain open areas of habitat needed by *C. ohlone.*

Habitat Scraping. In 2001, adults were observed on 13 of the 15 scraped plots, within a day or two after the scraping and also common on later dates. Adults at these scraped plots exhibited a full range of adults activities, including thermoregulation, foraging, mating, and oviposition. The two plots where adults were not seen were a farther distance away from the concentration of adult beetles and in an area of shallow soils. We also observed oviposition burrows at 12 of the plots and subsequently first instar larval burrows on 11 scraped plots. Most of the first instar burrows disappeared, apparently because the larvae died (not unusual for tiger beetle larvae). Some did progress to the second and third instar by July. There was less use of a larger number of scraped plots in 2002 than in 2001. Observations indicated adults were in only 6 of the 25 scraped plots, oviposition burrows in 5 plots, and first instars burrows in three plots.

Laboratory Studies. The small sample size did not allow for statistical analysis of the results of the fecundity and development studies, but we did obtain useful information on these life history parameters. Fecundities were highly variable among the females with a range of 2 eggs to 62 eggs per female over the four week period that some of the females survived. The three females (kept without males) collected on March 7 produced a mean of 3 eggs per female over a three-week period, while the four females (without males) collected on March 12 produced a total of 127 eggs and a mean of 42 eggs per female (Fig. 5). In this group some eggs were produced in each of the four weekly periods but most were in weeks two and three. The four females collected on March 20 and kept with males produced a total of 51 eggs (one female produced no eggs) in each of three weeks and an overall total of 13 eggs per female. Probable fecundity for females in the field could easily be 40-60 or more eggs during their adult life, if they obtain adequate feeding and if other conditions for oviposition are favorable. This level of fecundity seems average for tiger beetles, but fecundity has been reported as low as <20 to 300 (see appendix). The respective mean longevities of lab-reared adults (from their dates of field collection) for the above three groups of beetles was 28 days, 47 days, and 27 days

The durations of all three larval stages in the high feeding group were significantly shorter ($P<.01$) than the corresponding stages of the low feeding group (Figure 6). Mean development time from hatching to completion of the third instar (indicated by burrow plugging) was 109 days (about 3 weeks for first instars, 5 weeks for second instars, and 8 weeks for third instars) for individuals reared at a high feeding level (~ 1-2 prey items per day) and 161 days for those reared at a low feeding rate (1 prey item every other day; possibly comparable to feeding in the field?). None of these lab-reared larvae pupated and mortality increased greatly during the third instar plugging stage, apparently because of fungus contamination while they were inactive. Some of the remaining larvae were preserved for subsequent larval descriptions. Lengths of larval stages in the field-marked larval burrows could not as accurately determined as those in the laboratory but were generally similar to the low fed lab group.

SUMMARY AND DISCUSSION OF RESULTS

Distribution and Abundance. The results of our studies found that *C. ohlone* is currently present at 10 sites (and possibly the 3 unsurveyed ranch sites). Several sites have small numbers of adults and apparent marginal populations. The species no longer occurs at three other sites where they were found in the 1990's. Additional surveys should be conducted at

several areas which have potential habitat for *C. ohlone.* Our determination of adult numbers with index counts allowed us to compare relative abundance among the different sites in 2003 and 2004 but did not give a reliable estimate of actual population size. This is supported by a limited mark-recapture study at two sites where we marked over 3 times as many adults as were counted in the peak index counts. The discrepancy between these two methods could result from various factors, including adult inactivity, hiding in vegetation clumps, or their presence in other areas of the habitat which index counts may overlook. Index counts with species in more open habitats like sandy beaches or water edge sites may more accurately indicate population size because individuals are much more visible and without as many hiding places as in grassland habitats. Population studies by Knisley and Hill (unpublished reports) with several species of tiger beetles found that numbers from index counts were ½ to ¼ less than mark-recapture estimated done at the same time.

Both adults and larvae of *C. ohlone*, like most other tiger beetle species, are primarily restricted to open habitats with bare ground which is necessary for thermoregulation, foraging, and oviposition by adults and successful development by larvae (Knisley and Schultz 1997). Our work has confirmed that in these coastal terrace grassland sites, the great proportion of the open bare ground is on the trails and trail edges. Adults and larvae usually co-occurred and were limited to or most abundant in these less vegetated microhabitats. There were some significant variations among the sites. The trail edge microhabitat typically had more larvae than the trails, especially if the trails were more heavily compacted. Sites which had a significant number of open interior bare patches typically had more larvae than sites with little open ground.

Biology. Our limited study and observations suggest the biology of *C. ohlone* adults, including daily activity, feeding habits, mating and ovipositon, is similar to that of many other tiger beetle species that have been studied. It is most closely related to *Cicindela purpurea,* an upland species distributed throughout the United States. In the west this species occurs in mountain grasslands or meadows where adults and larvae are found among bare patches of clay soil (Knisley and Schultz 1997). The observed laboratory fecundity of *C. ohlone* is within the range of that reported for other tiger beetles, but this may be different from fecundity in the field. Adults in the laboratory were fed *ad libidum* and had available oviposition substrates, both of which may be severely limiting in the field (Pearson and Mury 1979; Pearson and Knisley 1985, Knisley and Schultz 1997). Based on our counts of oviposition burrows and more accurately first instar larval burrows at several sites, it seems apparent that the oviposition and recruitment rates in the field are far lower than what would be predicted from the maximum potential fecundity observed in the laboratory. For example, 50 adults (counted at several sites, but a probable underestimate of numbers) each laying 40 each should yield 2000 first instars (assuming 100% hatch, typical in the laboratory), a number that is many times the numbers of larvae seen at any site.

We did not study movement or dispersal but our finding of adults in the scraped bare patches indicates adults do move at least short distances within a site, possibly seeking new habitat patches for oviposition or foraging. Most species of tiger beetles are colonizing species that utilize small patches of transitory habitat. Some species are known to disperse long distances, but there is little in the literature about grassland species. However, because open patches in mountain meadows and other grasslands are also small and transitory, dispersal would

probably be a necessary life history characteristic for *C. ohlone* and related species. The length of the life span of individual adults is unknown, but they may survive in the field for several weeks like other species of *Cicindela*. The frequency of cloudy, cool, wet days during February and March would limit the number of days they are active and perhaps extend their life span beyond that of some other species which are more consistently active under warmer temperatures.

Seasonality and Life Cycle. The life cycle of *Cicindela ohlone* with the late winter-early spring adult activity pattern may be unique among tiger beetles in the United States. Adult collection records extend from January 29 until mid-May, but within any one year the length of the adult flight season is less. Rainfall and temperature patterns can alter the pattern by several weeks in a particular year. The life cycle is a modification of the typical spring-fall activity pattern of the most closely related species (i.e. *C. purpurea)*. In this species a cohort of larvae will mature to adulthood in late summer and emerge for 4-6 weeks in September to early October, then overwinter and re-emerge to mate and oviposit the following spring (April-May). The climatic pattern, especially the pattern of rainfall, in Santa Cruz County area has selected for the modified life cycle seen in the *C. ohlone*. The fall emergence has apparently been suppressed and adult emergence is delayed until late winter. Rainfall amounts are high and relatively consistent from January into March, then decline rapidly and become very limited to nearly nonexistent from May through October. By the time the dry conditions become persistent, most OTB larvae will have progressed to the second stage and be able to better survive the dry conditions and food limitations. If *C. ohlone* adults emerged in late March and April like other spring-fall species, they would be encounter a period of little and declining rainfall, and be susceptible to significant food limitation characteristic of dry seasons in the west. During this period the clay soils in these coastal prairie habitat becomes dry and "rock-hard" making it impossible for adults to oviposit, eggs to hatch and first instar larvae to dig their burrows. It is also likely that because of these dry conditions food availability would decrease and adults could experience food-limitation which would further reduce recruitment.

Larvae can more effectively tolerate the late spring to fall dry season because they can plug their burrows for long dry periods and obtain moisture at the bottom of their burrows. They will simply develop slower when there is less food. Emergence in December to January is probably inhibited by the lower and suboptimum temperatures (<16 C. most days) during this time. By mid-February and March temperatures have increased enough for adults to successfully thermoregulate and be active. Other species of tiger beetles throughout the U. S. have their adult activity patterns tied to the time of highest rainfall and when temperatures are suitable (over 16-18 C). For example, in southern Arizona, adults of all 17 species, even those that have spring-fall life cycles elsewhere, are active only during the summer July-August "monsoon" period.

Our laboratory studies suggest that a cohort of *C. ohlone* eggs could complete their development within a year and emerge as new adults the following year. However, that rate of development does not seem to be frequently realized in the field where food is more limited (possibly even more than our low food group) and periods of cool or otherwise unfavorable weather especially in the spring may reduce larval activity and consequently development time. Our field studies found that within a typical cohort of *C. ohlone* eggs, some individuals will complete development within one year but most will take two years. In either case, the adults

would emerge about the same time (February-March) but one year apart because of differences in the time that eggs were laid and the developmental progress of the larval instars. The relative abundance of third instars in the field during the late March through April period when adults are active suggest that these would be larvae from the previous year cohort and are in their second year as larvae, and will take two or three years to complete development (after they emerge the next year). The finding of mature adults in larval (pupation?) burrows in October suggests that some or many individuals may complete their larval development during the fall, in either one or two years, and pupate, but remain in the ground through winter before emerging the following February. This pattern of development was unknown in tiger beetles until demonstrated recently in a field study for *C. sexguttata* (Schultz 1998). This species is spring active but workers have frequently reported the occasional capture of an adult in the fall. We are not aware of any observations of *C. ohlone* adults in the fall of the year.

Asynchronous development and one year differences in development and emergence time are common in tiger beetles, and seem to result primarily from variations in the time of adult emergence, oviposition, egg hatching, and the amount of food obtained as larvae (Knisley 1987, Bauer 1991). Early hatching *C. ohlone* larvae and/or those that obtain more food can develop in one year while those hatching late or receiving less food will require two or three years. Additional variation in *C. ohlone* developmental patterns may be caused by the occurrence of extended periods of unfavorable weather that may result in late adult oviposition and hatching. As indicated above, we found adults emerged and peaked later in 2001 than in 2002, and also experienced a period of 10-14 days in March 2002 when weather conditions reduced or prevented adult activity.

LIMITING FACTORS, IMPACTS, AND THREATS

Cicindela ohlone is limited by both natural and human-related factors, but all of our current knowledge suggests that the primary negative impacts are the degradation of habitat by encroachment of vegetation (especially non-native annuals and woody species). Various workers familiar with these sites (G. Hayes, R. Morgan, others) have observed and in some cases documented the increase in non-native vegetation and a decline in bare open areas. These species may quickly colonize open areas and out-compete native grasses in many situations. Among the important invaders are French broom, velvet grass, filaree, Eucalyptus and various annual grasses. These nonnative plants are aggressive invaders that convert sunny, native grassland needed by OTB to shaded, closed, vegetated non-habitat. The OTB and other tiger beetles need open bare ground for visual searching and capture of prey, for oviposition, and for successful larval development. Historically, the coastal terrace grasslands were dominated by bunch grasses like purple needlegrass and California oatgrass, and had naturally-occurring patches of bare soil. .

As we indicated above most of the bare soil at most sites is that along trails and trail edges, but much of this limited habitat is negatively affected by the very factors that have caused it. Grazing cattle and mountain bikes are responsible for creating and maintaining bare soil on the trails at several of the sites, and without these the trails would become vegetated like the adjacent interior habitat. Cattle and bikes not only reduce the vegetation but also compact the soil. This may reduce the ability of non-native vegetation to colonize and persist in these areas.

However, the abundant daily movement of bikes and cattle along these trails during the adult flight season may also disrupt adult activity, especially mating and oviposition, and as a result limit larval recruitment. Our finding of most larval burrows along the trail edges and few in the middle portions of the trail itself is probably a result of these frequent disturbances affecting ovipositing adults or perhaps compacting soil so much that it is unsuitable for oviposition or for larvae to dig their burrows. The less compacted soil and sparse vegetation found along the trails edges may be more preferred sites for oviposition and larval development. This pattern was especially noticeable at three sites where trail impacts were especially heavy and large numbers of larvae were present either along the trail edges or in interior areas off the trail.

The most important natural enemies of adult tiger beetles are asilid (robber) flies and birds, both of which are opportunistic predators and thus may not be consistently significant limiting to most populations. A more important limiting factor for many species are larval parasitoids which had been reported to result in 20->60% mortality of some species. Three important parasitoids that have been found to attack many populations are a bombyliid flie (Genus Anthrax), a small ant-like wingless parasitoid wasp (Genus *Methocha*) and a related winged wasp (Genus *Pterombrus*) (Knisley *et al.* 1987, Knisley and Schultz 1997). The beefly adults hover over the open burrows of second and third instars and drop eggs into the burrow. The eggs hatch, the larva attach to the tiger beetle larvae, and eventually consume the host larvae when it is ready to pupate. Mortality rate is typically 100% for parasitized larvae. The wasp parasitoids find larval burrows by walking and searching in the habitat, sometimes making short flights to get to different areas. They enter larval burrows (second and third instars) sting the host larva and lay and egg on its underside. The hatched larva attaches and develops very rapidly (2 weeks), consuming and killing the host, then emerges as a new adult). Our considerable time in the field involved close examination of adults, larval burrows, and ground surface habitat, and if these natural enemies were present, we should have found them or evidence of their activity. We did observe bee flies at some sites, but these were not species that attach tiger beetles.

Food limitation is a significant limiting factor for most tiger beetles that have been studied (Palmer and Gorrick1979, Pearson and Knisley 1985, Knisley and Juliano 1985, Pearson and Vogler 2001, and it is probably important in limiting *C. ohlone.* Direct effects are death by starvation for both adults and larvae. More likely are indirect effects of low food availability such as prolonged development of the larval which can increase their exposure to parasites and other limiting factors. In a study of eight Arizona species, reduced feeding in tiger beetles has been shown to reduce survivorship of earlier instars, prolong development and produce smaller females which have reduced fecundity (Knisley and Juliano 1985). Although we did not measure prey abundance in the field we did notice during our frequent field visits that there were rather few potential prey arthropods compared to some other tiger beetle habitats we have studied). Competition with other tiger beetles is not a factor since there are no other co-occurring species. The most common co-occurring organism with *C. ohlone* is a small black lycosid spider that was conspicuous and abundant at all sites during the adult activity period. We did observe some feeding by beetles on this spider, but other cases of them being grabbed and rejected. They could compete for small prey items that might be used by adults and perhaps more importantly larvae of OTB.

Another factor that impacts OTB populations is weather. There are very frequent periods of several days or more of cool or rainy weather during the adult flight season that are unsuitable for adult activity. Also, there are many days when there is only an hour or two when it is sunny and warm enough for adults to be active. These conditions coupled with reduced prey activity and abundance may reduce adult energy resources and cause reduced survival, fecundity and recruitment of offspring. Soil and topographic characteristics at some sites are also apparent limiting factors. We found adults and larvae to be absent from areas along trails and portions of the sites where the soil is shallow and with extensive rocky layers at or near the surface. Adults and larvae are also absent from parts of trails and other potential habitat where water accumulates and is retained for long periods of time.

Overcollecting . Tiger beetles are a very widely collected group of insects with probably 100 or more serious collectors, many who seek to collect a good series of specimens for all species and subspecies for their private collections or perhaps for trade. Overcollection from these collectors is probably not a threat to most tiger beetle species because they are elusive, scattered throughout their habitat, and exist in several stages at one time. Species that are localized in small patches of habitat and in small numbers, like the OTB, could be negatively affected by overcollection if a significant portion of the population is collected several years in a row and before oviposition. It is certain that collectors have already taken many adults from one or several sites, and this may continue despite their listing. The Soquel site is probably the one best known to collectors, and perhaps coincidentally the numbers here have declined greatly in the past three years.

HABITAT MANAGEMENT, TRANSLOCATION AND RECOVERY

We believe the continued survival, viability and full recovery of the Ohlone tiger beetle will require a series of actions, including protection of all current sites, management of these sites to increase population sizes, establishment of several new populations by translocation of laboratory reared larvae, and additional research to direct management most effectively. These actions are discussed in some detail below and may serve as a basis for the development of a recovery plan for the species. Site specific management strategies are indicated in the last section of this report.

Site Protection and Habitat Management Strategies. Most of the current sites with OTB populations have now been at least partially protected from development or other activities that would greatly reduce the amount or quality of habitat. However, all of the 10 sites that currently support populations should be fully protected and managed to increased beetle numbers. Management and perhaps translocations should be considered at those sites where populations have been lost. Efforts should also be made to acquire or develop protection agreements for the three privately owned ranch sites if they currently support or are still suitable for supporting populations of the OTB. Additional field surveys to search for new populations should also be done as indicated previously in this report.

It seems quite apparent that the most important management strategy for the OTB is improving habitat quality by reducing vegetation growth (particularly non-native plant

encroachment) and increasing the amount of bare, open soils at the existing sites. Current sites without the OTB might also become habitat with appropriate management. The coastal terrace grassland sites are a disturbance-dependent community. Among the potentially important disturbances that may maintain open ground are grazing by various animals, fire, and other animal activities (gophers, pigs, ground squirrels). Many of the disturbances which have historically kept the habitat open and suitable for native vegetation (and OTB) have been reduced. For example, these sites have been free of fire since at least 1950, and other disturbances have also been limited.

New disturbance regimes or management strategies are now likely to be needed to open up the grasslands. Among the many possible methods of accomplishing this are scraping away vegetation, grazing, mowing, periodic burning, and creating or increasing trail use by foot traffic, mountain bikes or vehicles. Many of these activities have occurred at one or more of the OTB sites, and a reduction in vegetation has been a frequently observed consequence. However, many of these factors have not been systematically or quantitatively studied, and their effects on OTB numbers are essentially unknown. Designed experiments using enclosures or comparing numbers of OTB in relation to various management approaches are needed. The only apparent study that included direct effects on OTB was the vegetation removal study at Polski-Gross. This study suggested that scraping may be an effective strategy for creating bare ground. However, additional study is needed including trials with compaction of the scraped areas to reduce invasion of exotic plants and improve conditions for oviposition and larval development. The use of mowing may be quite effective for reducing vegetation height and improving habitat, especially along trail edges which are often favored sites for oviposition if not too densely vegetated.

Some workers have suggested that fire has probably not been a long-term factor in these coastal terrace habitats (K. Lenington, OTB workshop). Evidence from periodic controlled burns at Marshall Fields indicate that burning does not create bare ground (Fusari and Hayes, OTB workshop). However, additional studies on the potential of fire for improving OTB habitat are being conducted at GW and have initially shown potential for reducing vegetation (T. Hyland, personal communication). Mowing along trails0 has been done for several years at Pogonip. Grazing may offer the most promise for reducing vegetation (especially non-native species at these sites. Grazing has occurred for many years at the Moore Creek and Poliski-Gross and has been very effective in reducing plant cover, height and thatch build-up, but with some negative effects as noted above. Plans at these sites are to continue a grazing regime that will hopefully reduce thatch and annual grasses and maintain trails and patches of bare soil. Vegetation reduction by use of goats in a limited area for a short time period was conducted at Pogonip in 2004 and seems to have been very effective. Management strategies like grazing and increased trail use (mountain bikes) will likely contribute to the needed open habitat for OTB but some adults and possible some larvae may be killed by these activities.

Translocation. Because of the recent success with laboratory rearing of the OTB and recent evidence of successful establishment of a population of the Northeastern Beach Tiger Beetle by translocation, it is probable that the translocation of larvae of the OTB to unoccupied sites or to existing sites to supplement populations could be an useful recovery strategy. Field collected females will readily oviposit in the lab and individual females could probably produce

30-70 eggs. These could be reared to the second or third instar and translocated to field sites in Santa Cruz County. Translocations of the field-collected third instar larvae of *Cicindela dorsalis* from Virginia to New Jersey over a four year period has resulted in establishment of an adult population of over 750 individuals at the translocation site. The larvae successfully survived the winter, pupated and emerged under habitat conditions that were likely more severe than in Santa Cruz. Laboratory-reared larvae could also be used in controlled field experiments to study various life history factors and management approaches.

Research Needs and Other Recovery Actions. Much important information on the Ohlone tiger beetle has been learned in recent years from our work on this project and from several other workers. Additional research is needed to effectively manage and recover this species. One of the most important needs is to achieve a better understanding of the effectiveness of various management strategies to improve habitat conditions. Ideally, this would involve the use of controlled experiments or trials in the field. The potential negative impacts (and positive) of mountain bikes and cattle grazing have not been quantified. A management strategy that might work to increase the benefits and reduce the negative impacts of mountain bikes would be to place signs along current bike trails at some sites directing riders to use an adjacent parallel area for riding. This would protect the existing trail and create a new trail. Moving the signs on alternate years might be successful in creating more habitat and reducing run-overs. Signs could indicate the conservation purpose of this action.

Some additional research on the biology of *C. ohlone* is needed for effective management recovery. Determining the actual population sizes (adults) at each of the sites and dispersal behavior will provide important information on the viability and interaction of the populations and the species. Mark-recapture studies will probably be needed at one or several sites and combined with index counts to determine how these two methods of population estimation are related (i.e. how much are the index counts underestimating population size). Knowing about movement of adult beetles among sites is necessary for management considerations and possible needs for creating corridors and establishing new sites. Dispersal information could be determined as a part of mark-recapture studies. More information is also needed on the specific soil and other habitat characteristics that define the habitat of this species.

OTB SITES: THEIR HABITAT CHACTERISTICS, BEETLE POPULATIONS, AND MANAGEMENT NEEDS

Scotts Valley. This site is adjacent to Vine Hill School and ball fields. A subdivision with 233 homes was proposed for this site but that project was voted down in 1998. Alternative plans including protection and management for the OTB are now underway, and in 2004 new fencing was placed around the site and "No Trespassing-Sensitive Wildlife Habitat" signs added. This site is isolated from the other OTB sites by over 10 km. It includes a relatively large area of potential habitat, but extensive surveys of the site by Arnold indicated beetles were restricted to a small area (of several acres) in the southern and southwestern part of the site. Surveys of adult numbers conducted on multiple dates in 2000, 2003 and 2004 indicate a relatively large population. Peak numbers for these three years were 59, 66, and 33, respectively. Thorough

surveys of larvae at this site were done only in 2003 when a count of over 500 larval burrows were counted in June and July. This was more than twice the numbers of larvae counted at any other site. Most larvae were third instars (<12% seconds), thus indicating excellent oviposition and subsequent recruitment at this site by the 2002 (and possibly 2003) adult cohorts. However, the adult numbers at this site in 2004 were much lower than we would have expected from this large population of larvae.

Like all other OTB sites, there is too much plant cover and too little open, bare ground. The amount and height of vegetation at this site has been reduced moderately by horses that use this site and also by a population of California ground squirrels. Most of the adults and larvae of *C. ohlone* are restricted to the area along the main horse trail and in a sparsely vegetated patch in the area of active ground squirrel burrows. We observed that the height and density of vegetation at this site was much greater in March 2004 than in 2002 or 2003, apparently because horses have been removed (temporarily?) from the site. This could reduce oviposition, recruitment and larval survival of the 2004 cohort.

The primary management need for this site is to create more open habitat by reducing the height and density of vegetation. The narrow trail which supports much of the beetle population must be maintained. Horse grazing would probably be an acceptable management tool at this site, but mowing may also be used to reduce vegetation height along the trail edges and perhaps in some of the interior habitat. The amount of horse use at the site in the recent past did not seem to have any negative effects on the beetle population. Bare patches should be created by scraping and compacting of small areas on a regular basis, in the areas of primary beetle habitat and in areas away from the trail edge. Several 3 m wide x 10-20 m long scrapes perpendicular to the trail along its upper section would be appropriate. The ground squirrels should not be eliminated because they seem to be having a significant effect in reducing vegetation and creating open patches for adults and larvae.

Soquel. A botanical assessment was conducted in 1991, plant communities were mapped in 1997 study, and OTBs surveyed in 1993. The primary plant communities found at this site were coastal terrace prairie, non-native grassland and mixed grassland/scrub mosaic. The coastal terrace prairie on this site includes 9.5 acres on the top and side slopes of the marine terrace within the central and southwestern portion of the project site. Two endangered plants, Santa Cruz tarplant and Gairdners yampah, occur in this community at this site. The native grassland is intermixed with non-native grasses which are abundant in the extreme southwestern portion of the site on the steep slopes, and also near the gate at the north end of Benson Avenue. A 21-house subdivision was proposed for this site, and would have eliminated all of the OTB habitat. An alternative proposal in the final EI report proposed that most of the suitable habitat be set-aside and managed to reduce non-native vegetation and to enhance habitat quality. Action is currently pending, and there is no evidence of vegetation management at this site. This site is the type locality for *C. ohlone.* It is surrounded by a housing development and steep slopes of non-habitat. This is one of the lowest elevation sites (300'), close to the ocean, and isolated by over 5 km from the nearest site, Pogonip which has had few or no beetles. Nearly all adults and larvae of *C. ohlone* are along the 250 m long by 3 m wide path passing through the length of the site. Unlike some sites we have not seen adults or larvae in the interior area of this site which has essentially no bare patches.

Adult numbers counted at this site have varied considerable but include a high estimate of over 150 individuals in 2002. This estimate was based on a week-long mark- recapture when 150 different adults were marked. Since very few of the adults captured in the last two days of this study were marked, a population size of significantly larger than 150 almost certain. During this same study, the highest number of individuals counted during daily index counts was 50. Other peak adult counts were 23 in 2003 and only 7 in 2004. Total larval numbers were 99 in 2002, 48 in 2003 and 95 (most first instars) in 2004. The low adult numbers in the last two years and low number of larvae in 2003 suggest a significant population decline at this site. We noticed a rapid, significant decline of adults during early March of 2003 (while other OTB sites maintained high numbers during this period). We hypothesize this may have been due to a several week mini-drought causing a drying out of this site (since the soil surface was noticeably dry) and adult mortality or inactivity. This could also have accounted for the low numbers of larvae at this site later in 2003 and few third instars in 2004. Another possible cause could have been loss of adults from collecting, since this site is probably the site best known by collectors.

Management to reduce vegetation cover and height is badly needed at this site since there are essentially no bare soil patches beyond the trail. Foot traffic and children playing and riding bicycles seem to be what are keeping the trail open. The vegetation is also higher at this site than most others. We do not believe the amount of foot traffic and other human activity at this site is having a negative effects on the beetle population, but more likely it is beneficial. To improve habitat, we recommend mowing to reduce vegetation height to <10 cms and removing thatch in late winter. Also needed is the creation of a series of bare patches of soil by scraping and compacting several 3 m x 10 meter sections perpendicular to the trail on each side.

Pogonip. This large site was established as a city preserve in 2000 and includes a relatively large section of coastal terrace prairie (potential habitat) found in the main meadow; other potential habitat is along Spring Trail, at Haunted Meadow and other smaller meadow areas. Mima mounds in the main meadow southwest of the existing Ranger facilities, are

dominated by non-native vegetation. Adults and larvae at this site have been found in a localized area west of the Clubhouse along the Prairie Trail and just south on the Pogonip Creek Nature Loop. Regular annual surveys of the site have produced only very larvae (less than 10) and few adults, never more than 20 (in a 2001 survey by Lenington). We found no adults at this site in our 2002 and 2003 surveys and only a few probable larval burrows. Three adults were found in the 2004 survey.

Non-native vegetation is having a significant negative impact on OTB habitat at this site and may account for the apparent near-extirpation of beetles from this site in recent years. Vegetation cover in the areas where beetles have been found has been near 100% with very few open soil patches. Several attempts to reduced vegetation cover and improve habitat at this site have not been successful because of rapid colonization by non-native species. The key trails in this area have been mowed to reduce vegetation height and to improve the habitat for beetles, but the absence of any open patches prevents adult foraging, oviposition sites, and larval development. Beyond the immediate trails, vegetation height and thatch are so great that beetles cannot use this part of the habitat.

Habitat management first, and translocation of larvae will probably both be needed to produce a viable population of *C. ohlone* at this site. The sporadic presence of few beetles at this site suggests it is not providing suitable conditions for the population to build up. Initial habitat management should be in the main meadow area west of the clubhouse and range station where beetles have been found. Management options for this site are limited by certain restriction related to its public use. Fire will probably not be a good option as past experience has indicated. Grazing by goats was tried in 2004 and seems to be a viable option for vegetation management at this site. Alternative options that might be suitable include mowing of a large section of this main meadow to reduce vegetation height to less than 3-4" and if possible, some procedure to remove thatch. This would probably be best done in mid-February near or before the start of the adult flight season. It may need to be repeated in late March-early April. In addition, there should be a series (5-10) of approximately 3 m wide by 20 m long sections of the meadow scraped of surface vegetation and then moderately compacted with vehicle run-overs. Compaction will help to slow vegetation recolonization and make soil conditions more suitable for oviposition and larval development. These scrapes could be situated adjacent and perpendicular to the existing trails. Existing trails should continue to be mowed. Since the current population is so low and not viable, re-establishment and recovery of the OTB here will be slow and possibly not successful without supplementation. One solution to this would be larval translocations using laboratory reared second instar larvae placed in surrogate burrows on scraped patches in late March to mid-April.

Polski-Gross. The upper terrace at this site supports two grassy meadows. The northern meadow is dominated primarily by annual grasses and other introduced plants, while the southern meadow is dominated by Mima mounds and several rock outcrops and thinner soils with a greater proportion of native grasses and forbs. The OTB was studied at this site in 2001 by Arnold who conducted adult surveys and examined distribution within the site. Most adults were found around the periphery of mima mounds and along the dirt trails, but greatest densities were along the trails. Significant numbers were also found in loose soils from gopher diggings. Recent surveys indicate most adults were restricted to the trail area of the north meadow with

few among the Mima mounds but some in the southern meadow. Adult surveys at this site produced peak counts of 165+ in 2002, 53 in 2003 and only 15 in 2004. The high count in 2002 was based on the number of different individuals marked during a 4-day mark-recapture study. The index count during that time produced a count of 45 adults. The numbers of larvae were 137 in 2001, 58 in 2002, 57 in 2003, and 17 in 2004. The apparent decline of adults and larvae at this site in the past two years may be due to negative impacts from relatively heavy cattle use along the trail or to unknown factors.

This site should be managed to reduce vegetation cover and height, and to reduce soil compaction and burrow trampling by cattle. Cattle are providing moderate vegetation control during the several weeks that they are grazing the site in late winter (Feb-March), but the timing of their grazing and the effects of their activities on the trails where OTB's occur must be more carefully controlled to limit the negative effects on the OTB. We have determined significant compaction of the soil on the trails to the extent that most of the trail surface is unsuitable for adult oviposition. Cattle also seem to be disturbing oviposition and larval burrows by compaction and cutting off sections of soil along the raised edges of the trail.

One recommendation to correct the above problems and improve the habitat for OTB at this site would include the use of fencing to relocate cattle activity away from the main trail. Specifically, the existing trail (along with a 2-3 meter buffer) that is heavily trampled by cattle should be fenced off completely (possibly with electric fence). The area within the fence should be mowed to maintain vegetation height at < 10 cms during the adult flight season. This plan would ideally retain the beneficial effects of cattle on vegetation management and also create some additional new trails or open soil by diverting cattle to adjacent areas. With the fencing in place, it may also be possible to graze cows at the site for a longer period each year. An alternate strategy or additional management approach would be to create several bare patches (3 m wide by 10 m long) in the interior areas by scraping off the vegetation and compacting the scraped area.

Moore Creek. This site, established as a city preserve in 2001, supports 12 distinct types of plant communities, including three grassland communities: high diversity coastal terrace prairie-wildflower field, medium-diversity coastal terrace prairie, and low-diversity/non-native grassland. These grasslands occupy the tops of terraces. High diversity coastal terrace prairie occurs in areas of shallow rock layers and includes a higher diversity of native and non-native wildflower species, and is dominated by sod and tussock-forming perennial rye-grass, soft chess, ripgut grass, foxtail and slender wild oat. These have heights of 2.5-4.0 feet in good rainfall years. The western terrace located between two branches of the eastern tributary of Wilder Creek and the south-central portion of the Meder Street area are good examples of this community. Medium diversity coastal terrace prairie occurs in the northern section of the property and includes both native and non-native grasses and wildflowers that fluctuate in dominance locally. Non-native grasslands dominate in the southern terraces, formerly used for intensive cattle grazing. These grasslands are generally found on fine-textured, clay-rich soils, which are moist to waterlogged during winter rains and dry during the summer and fall (Holland 1986). Mima mounds, raised hillocks of uplands generally interspersed with seasonal wetlands and drainages, are also present. The site has a long history of cattle grazing and in recent years 40-50 head have been present for several 6-8 week periods each year.

Moore Creek currently has a large and viable population of *C. ohlone*. Our counts of adults along the trails do not include possibly significant numbers occurring in the interior areas of the site. Adult surveys at this site produced peak numbers of 46 adults in 2004, 108 in 2003, and 35 in 2002. Numbers of larval burrows were 111 in 2002, 75 in 2003 and 63 in 2004. Adults were mostly on and along the edges of three of the heavily to moderately used cattle trails: a double track vehicle and cattle trail on the south side going up the hill (west), a narrow cattle trail near the north side of the site also going uphill and the lower cattle and vehicle trail going north to south. Our searches of the habitat interior also indicated that this is one of the few sites that has significant numbers of adults and larvae in the interior beyond the trails, apparently because there are more open bare patches than at most other sites. These open patches where adults and larvae were found are primarily the result of a high level of gopher activity that continually creates suitable patches for beetle colonization. Cattle have both positive and negative effects at this site. They reduce vegetation cover and height and are the main factor maintaining trails. In 2002 many adult beetles were found along a 300 m length of very heavily used cow path where vegetation cover was sparse (0-40%) and the soil was severely cut and compacted. A summer survey of this trail produced no larvae, possibly because of the effect of cattle on oviposition and larval recruitment. We did find a total 96 larvae in three other locations, some adjacent to the trails but others 15-30 meters away in sparsely vegetated patches within the meadow.

This site may have the most suitable habitat and may support the largest numbers of *C. ohlone* (because of uncounted beetles in interior habitat patches), but it could be improved to support a larger population of beetles by management to reduce the probable negative impacts from cattle and create more open areas. We recommend that several of the most heavily used trails be fenced off during the adult flight season and when larvae are in the first instar (typically mid-Feb. to early April) to reduce compaction and trampling. The two trails that showed greatest use in 2003-2004 were the narrow cattle trail near the north side of the site and the wide vehicle trail near the southern end of the site. The north cattle trail is especially compacted and

cut from cattle trampling in the past two years, and has produced little or no recruitment. Mowing within these fenced areas may be needed to control vegetation during the flight season and could be used along the edges of other trails through suitable habitat. In addition to this, relocation of the cattle feeding and watering areas could further divert cattle from these heavily used areas and possibly create more open areas elsewhere. Although the gophers are creating open areas, many of these may be too small or too short-lived to sustain larvae through their life cycle. Additional suitable habitat could be produced by scraping two-three bands (3 m wide) across the width of the site (north to south) on the slope. This could be done in mid-later February at the beginning of the adult flight season.

Moore Creek Northeast (Meder St.). This relatively small southwestern section of the Moore Creek Preserve consists of a narrow strip of meadow separated by dense woodland and a ravine. A horse/ walking trail runs along the length of the site on the south side. This trail is where small numbers of adults and larvae of *C. ohlone* previously were found, but surveys in the past four years (2001-2004) produced no adults or larvae. This trail continues on to a private ranch where beetles were found in the late 1990's. The cause of the apparent extirpation of OTB's at this site is unknown, but the size of the population and available habitat may have been small and perhaps marginal. The trail was graveled several years ago, has evidence of compaction, and a part of it is shaded. Some of the habitat was apparently lost by conversion to a pasture by a adjacent landowner. There is also woody vegetation encroachment at the site that seems to be reducing the already limited interior open areas. We are uncertain if the amount and type of trail use at this site is having a negative impact.

Management approaches at this site should include vegetation reduction, including control of the woody growth in the interior and the creation of bare patches by scraping and compaction adjacent to the current trail. The effect of trail use at this site is unknown but the compaction and gravel are probable negative factors. However, the isolation (by non-habitat), small size and limited amount of habitat at this site suggest it may only be capable of support a small and possibly non-viable population. Translocations would probably be needed to re-establish a population.

UCSC-Inclusion Area A. This site adjacent to Empire Grade on the north side includes a relatively large sloping meadow bisected by a wide partially gravel-covered road and several other narrower dirt (mountain bike) trails throughout the grassland. Most of the adults and larvae at this site have been found at several separate patches long the main road, especially in the section farthest from Empire Grade, near the end of the site. Apparently, the numbers of adults declined after gravel was placed on the main trail in the late 1990's. A survey in the mid-1990's produced a count of ca 30 adults, but multiple surveys in recent years produced peak counts of 6 in 2002, 14 in 2003, and 4 in 2004. This apparent decline may be due to some of the best habitat being lost because of the graveling. Larval surveys have been limited but the relatively thorough survey in 2003 yielded a count of 20 burrows. The main central trail and other trails receive heavy mountain bike and pedestrian use throughout the year that have some negative impacts on the beetle population. The low numbers of adults and larvae at this site, especially relative to its large size and large amount of potential habitat may be a result of the dense vegetation cover throughout nearly all of the interior with very few open bare patches and heavy trail usage. Gopher activity is present but does not seem to be producing many suitable open patches for

beetles. Cattle are also grazed on the site for several short periods each year to manage vegetation and probably are beneficial in reducing the amount of plant cover. There is no evidence that they are producing suitable trails for OTBs.

The size and nature of this habitat suggests that effective management might be able to significantly increase the OTB population. Increased cattle grazing might be effective in reducing vegetation height and cover, but must be monitored to prevent heavy trampling in present beetle habitat. Additionally, should probably be some scraping to create open areas. The best approach may be to scrape several long (30-50m) compacted patches in the far portion of the site (away from Empire Grade) where most adults and larvae have been seen.

UCSC, Marshall Fields. This site on the east site of Empire Grade consists of several relatively small meadows that are separated by dense woodlands. This site is being invaded by velvet grass and tall fescue. A few adult OTB's were found at two of the northernmost meadows (close to Empire Grade) several years ago, but none have been found at these in the past three years. These meadows are relatively small with tall vegetation, little open areas (except the bike trails) and experiencing encroachment by trees and shrubs. There are two larger meadows that have large OTB populations. The largest of these is the MFF, the front meadow that borders Empire Grade on the south. This meadow is bisected by a wide, heavily-used gravel road that apparently had moderate to high numbers of OTBs before it was graveled in the mid-1990s. The beetles (both adults and larvae) are now found along scattered sections of two mountain bike trails that are along the north and east borders of the meadow. Peak adult numbers here were 78 in 2003 and 47 in 2004. Larval numbers were 31 and 142, respectively. Only a few adults and larvae have been found in the interior of this site. The other current Marshall Fields site is the back meadow (MFB) that is about 400 m southeast of the main meadow. It is smaller than the main meadow and includes several mountain bike trails that are less used than those in the main meadow. Adults and larvae are present at relatively high densities along several sections of the bike trails and also have been found each year (especially in 2004, Table 4) in interior areas that have been scraped by pigs. Pig scraping is very extensive at this site and has provided a significant amount of habitat for adults and larvae. Consequently, we have found more interior adults and larvae at this site than any other.

Management at this site in the past few years has included blocking of bike trails by fencing which seems to have been effective in reducing runover of adults. However, the trails trails and trail edges which support most adults and larvae are narrow and heavily compacted. Most oviposition and larval burrows are on the trail edges which have reduced vegetation. Mowing of the trail edges may make them more suitable as oviposition and larval habitat so this approach might be tried. More open interior habitat is needed in the front meadow so scraping and compaction of patches is recommended. Pig scraping in the back meadow is providing a considerable amount of open interior patches but these are fairly quickly covered with plant growth. Still, they probably do support oviposition and larval development because overall vegetation cover is reduced. Another problem at the Marshall Field sites is reduction of beetle habitat by the encroachment of woody vegetation (Eucalytpus and other trees and shrubs) around the edges of the meadows. Cutting or other vegetation control is needed for this problem.

Wilder Ranch State Park, Gray Whale. This very large site includes numerous meadow and grassland areas of potential OTB habitat. However, extensive survey work at this site in the past two years (by Tim Hyland) has not yielded any new locations with beetles. A large population of OTB's has been found in one of the interior meadows, primarily along Chinquipin Trail and two several side trails in the same meadow. Some of the former habitat, the road at Twin Gates on Empire Grade, at this newly acquired addition to the state park was lost by placing gravel on the road. The current main habitat for OTB is a continuation of this entrance trail which passes through a meadow about a mile from Empire Grade. Initial systematic surveys at this site in 2000 produced no adults, but were found first at this site in 2001. Our surveys produced peak adult counts of 58 in 2002, 35 in 2003 and 38 in 2004. Adults were along the main heavily used trail (Chinquipin) and on two adjacent side trails. Total counts of larvae were 122 in 2002, 154 in 2003, and 51 in 2004.

Current management at this site includes placement of fencing during the flight season along the three main OTB trail sections where adults occur. This has been done in both 2003 and 2004 probably has reduced to an unknown extent mortality to adult beetles from mountain bike runovers and positively affected adult oviposition and larval recruitment in these key habitat sections. The trail closures have also diverted bike traffic around the fences and created new open trails which could increase beetle habitat. A fall burn in this main meadow was carried out in 2003 and has reduced vegetation density and cover. These management strategies should be continued, particularly the fencing during the flight season.

Additional management that may further improve the OTB habitat at this site should include scraping and compaction of 1-2 swaths (3m wide x 20 m long) on each side of the main road, probably in late winter near the beginning of the adult flight season. Another recommendation is beginning a program of progressive cutting of trees and shrubs that are encroaching onto the meadow and causing shading and reduction of habitat.

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Table 1. Maximum adult numbers of *Cicindela ohlone* and selected habitat parameters at Santa Cruz County sites. Site #'s refer to map locations in Figure 1.

Site #	Site Name	Site Elev. meters	Habitat Area in sq. m. x1000	Trail Survey Length(m)	Length of trail occupied by larvae	Max.Adults # per 100 m of Trail	Max. Adult Count in 2004	Max.Adult Count in 2003	Adult Count in 2002	Max.Adults Counted off Trail (2003)	Site Threats, Impacts
2	Scotts Valley	223	25	250	180	30	39	75	?	11	Moderate-walkers,horses, play activity
1	Soquel	97	15	300	300	13	7	23	40(150+)*	0	Moderate-walkers, bikes
5	Pogonip	60	20	150	250	0.2	3	0	0	0	Light-walkers
13	Poliski-Gross	70	60	650	400	8	13	53	55(165+)*	14	Heavy-short period of cattle trampling
3	Moore Creek	73	50	650	150	17	46	108	35	16	Heavy -short period of cattle trampling
4	UCSC-MF Main	304	40	400	70	20	47	78	?	5	Heavy- bike use, some walkers
6	UCSC-MF-Back	304	20	225	80	20	29	37	?	24	Moderate -bike use on trails
14	Gray Whale	292	50	325	80	29	38	35	58	6	Heavy -mt. Bike use, walkers
10	UCSC- Incl AA	140	90	1100	75	1.3	3	14	6	3	Heavy-bikes,walkers; periodic cattle use
16	UCSC-Nat. Area	304	15	150		4.8	4	6	2	0	Moderate/light-walkers, some bikes
	Subtotal		**385**								
7	UCSC-MFN	300	6	100?			0	0	0		Moderate-bike use
15	UCSC-MFN	300	4	75?			0	0	0		Moderate -bike use
11	Moore Ck.-Meder	95	10	200			0	0	0		Moderate?-walkers
9	Private Ranch	125	50	?			?	?	?		?
12	Private Ranch	122	50	?			?	?	?		?
8	Private Ranch	107	50	?			?	?	?		?
	Total Area		**555**								

* refers to toal number of adults collected during a 4-day mark-recapture period.

Table 2A. Adult index count results at all OTB sites for 2003

Survey Date	OTB Transect Counts for 2003										
	Soquel	Pol-Gross	Scot.Val	MFMain	MFBack	IAA	Gr Whl	Moore Ck	Pogon	MederSt	Total
17-Jan	0	0	0	0	0		5				5
27-Jan	15	24	18								57
31-Jan				26	15	7	11	5			64
3-Feb	21	37	22				35				115
4-Feb				35	24	10	6				75
7-Feb	23	34	18								75
9-Feb				30	27	10					67
10-Feb							1				1
17-Feb	16	29	26								71
18-Feb				41	28	14	15				98
20-Feb							21				21
21-Feb			13								13
22-Feb	2	53	14	78	27						174
28-Feb	8?	3	?	3	37						43
1-Mar	9	38						55	0		102
2-Mar			55	47	22		29			0	153
4-Mar							2				2
5-Mar	3	36	75	42	34					0	190
6-Mar	4					12		108	0		124
8-Mar		17		28	25	9		36			115
9-Mar	5		47				22				74
12-Mar							20				20
15-Mar	2		15	11	7		6				41
22-Mar		12		19	16		4				51
23-Mar	3		17			5					25
26-Mar				30			10				40
27-Mar		4		30				62			96
28-Mar			26			6	15				47
29-Mar		8		20				49			77
30-Mar			26								26
6-Apr		2		7	8	2					19
9-Apr							5				5
13-Apr	0	0	0	0	0		0	2			2
14-Apr							3				3
17-Apr				0	0	0	0				0
Totals	103	297	372	447	270	75	205	317	0	0	2086
Mean # per Site	7.9	19.8	24.8	26.3	18	7.5	10.8	45.2	0	0	59.6

Table 2B. Adult index counts results at all OTB sites for 2004

Survey Date	OTB Transect Counts f for 2004										
	Soquel	Pol-Gross	Scot. Val.	MF-Main	MF-Back	MF-Pig*	IAA	Gr Whl	Moore Ck	Pogonip	Total
9-Feb								2			2
10-Feb			6	10	7	5	2				30
11-Feb	2	2					2	9	13		28
14-Feb			14	12	11	7	2	11			57
28-Feb			28	25	20	13	4	29			119
2-Mar	3		34	29			4				70
4-Mar					24	22			22		68
6-Mar				35	29	24		38			126
7-Mar	6	13	39				3				61
10-Mar	7	10							46	3	66
11-Mar				47	25	19		30			121
12-Mar			33								33
14-Mar			29								29
20-Mar			24	34	21	17	2	22			120
28-Mar			19	23	15	10	1	14			82
29-Mar								11			11
3-Apr			9	11	6	4	1	6			37
10-Apr			4	6	8	2	0	7			27
17-Apr			0	0	0	0	0	0			0
Totals	18	25	239	232	166	123	21	179	81	3	1087

* Refers to pig scraped areas of interior habitat

Table 3. Numbers of Larvae Counted at OTB Site, 2002-2004, and Their Distribution Among 3 Microhabitats (Trail, Trail Edge, Interior)

	Trail	Trail Length		Numbers of First-Second-Third instars and Totals 2002-2004					
Site	Length	Occupied	Jul-02	# from	Jul-03	Mar-03	# from	Apr-04	# from
	meters	meters	# Larvae	2001	# Larvae	# Larvae	2002	# Larvae	2003
Soq	300	300	99(6-43-50)	50	0-6-42	31 (1-5-25)	25	95 (70-4-21)	21
GW	200	70	122 (7-57-58)	58	154(27-24-103)	46 (1-15-30)	30	51 (35-2-21)	21
MFM	400	100	ns		29 (1-3-25)	31(2-9-20)	20	142 (125-6-11)	11
MFB	225	80	44(10-23-11)	11	57 (15-1-41)	50 (1-5-44)	44	156 (136-2-18)	18
MFBpig			145 (23-41-81)	81	ns	57 (1-8-48)	48	328 (314-2-12)	12
PG	250	250	58 (37-1-20)	20	37(0-11-16)	24 (0-2-22)	22	17 (12-0-5)	5
MC	650	150	89 (0-0-89)	89	ns	55(1-14-38)	38	54 (46-1-7)	7
SV	250	140	ns		546(3-21-522)		83-32-274	389(83-32-274)	274

Distribution of Larval Burrows in 3 Microhabitats 2002-2004									
		2002			2003			2004	
	Trail	Edge	Interior	Trail	Edge	Interior	Trail	Edge	Interior
Soq	29	70	0	10	18	0	18	7	0
GW	33	89	0	14	48	40	5	53	22
MFM	68	20	0	24	57	0	18	141	7
MFB*	8	ns	169	20	58	60	71	85	316
PG				12	28	6			
MC	12	24	75	14	33	28	7	47	29
SV							25	56	307*
Totals	150	203	244	94	242	134	144	389	681

*Most of interior at this site is pig scraped area
**Large sparsely vegetated area, including part of trail

Table 4. Development and Survival of the 2001 Cohort of 180 Oviposition Burrows at PG

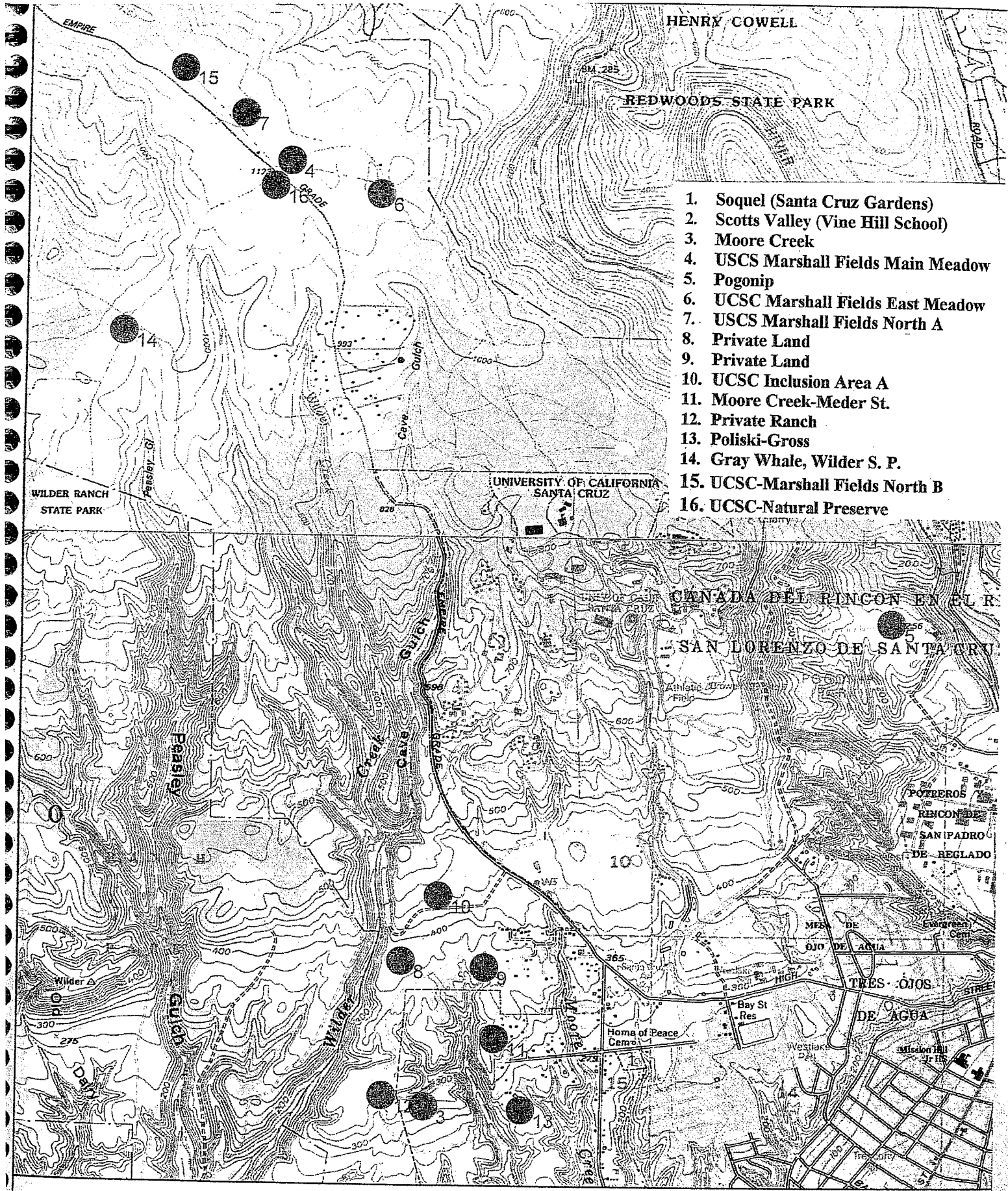
	Ovipos.	Burrow Diameter of Larvae										Percent
Date	Burrows	2	2.5	3	3.5	4	4.5	5	5.5	6	Total	Survival
		1st	1st	2nd	2nd	2nd	3rd	3rd	3rd	3rd	Larvae	
March	180											
April,2001		106	23	8							137	76
May		39	37	18	11	7					112	62
June		4	18	25	16	11	14	2			90	50
July		1	9	1	14	0	35	0	19	9	79	44
August			2	0	7	6	9	11	26	3	64	36
September				3	5	4	8	14	13	2	49	27
Spring 2002							2	4			6	
Spring 2002											11 Adults	6+11=9.4

Overall survival from egg to adult or continuing larvae = 9.4%
11 adults emerged after 1 year; 6 larvae continued into second year

Table 5. Habitat Parameters Measured at *C. ohlone* Sites in 2003 and 2004
Parameters include % vegetation cover, # 25 sq. cm. Or greater bare patches (per 1-sp. meter frame), soil moisture, soil compaction (in psi), and numbers of animal disturbances

		April 2004 Habitat Study											March 2003 Habitat Study					
													Vegetation (%) and No. Open Patches					
Study	% veg	No. open	Veg.	No.	No. Pig	Cattle	% Moisture			Compaction (PSI)			Trail		Edge		Interior	
Sites	cover	patches	Ht(cm)	goph.	scrapes	Tracks	Trail	Edge	Inter	Trail	Edge	Inter	%	No.	%	No.	%	No.
Soquel	98.6	3	24	15	0	0	92	95	87	266	108	72	52	8	83	4	100	0
Pol-Gross	98	6	18	28	0	12	94	93	80	247	110	81	70	7	95	1	99	0
MarFld M	96.5	10	15	24	22	0	92	93	85	191	90	29	42	10	78	1	88	1
MarFldBck	92.1	16	19	13	28	0	83	83	90	178	98	36	40	9	91	1	94	1
Scot.Valley	98.1	6	21	13,12*	0	0	93	96	93	176	95	60	50	15	87	2	83	2
Gr.Whale	94.6	13	15	14	15	0	81	87	86	206	113	68	18	21	82	4	84	3
Moore CK	93.4	21	15	24	0	31	98	98	97	190	89	64	25	6	92	0.5	89	2
UCSC-IAA	99.6	2	17	23	0	0												
Pogonip	99.8	0	33	8	0	0												

* refers to ground squirrels not gophers



Name: FELTON
Date: 5/4/2004
Scale: 1 inch equals 2222 feet

Location: 036° 59.8242' N 122° 03.8001' W
Caption: FIG. 1A. KNOWN SITES FOR CICINDELA OHLONE

Name: FELTON
Date: 5/4/2004
Scale: 1 inch equals 3076 feet

Location: 037° 01.9193' N 122° 00.6375' W
Caption: FIG. 1B. KNOWN SITES FOR C. OHLONE

Fig. 2 Mean monthy rainfall and high and low temperatures at Santa Cruz, CA

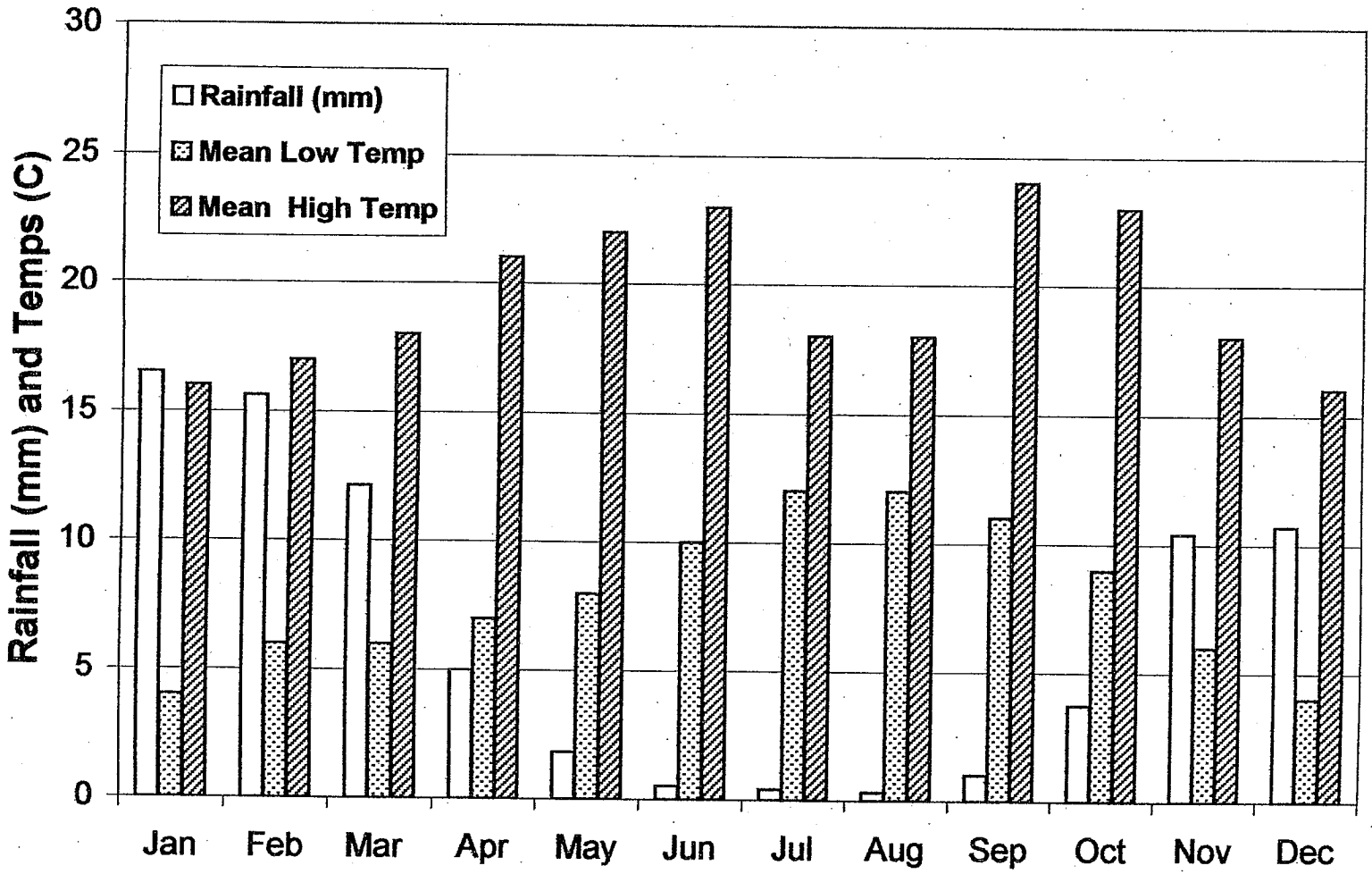


Fig. 3. Adult Ohlone Tiger Beetle counts summed for all sites on representative dates in 2003

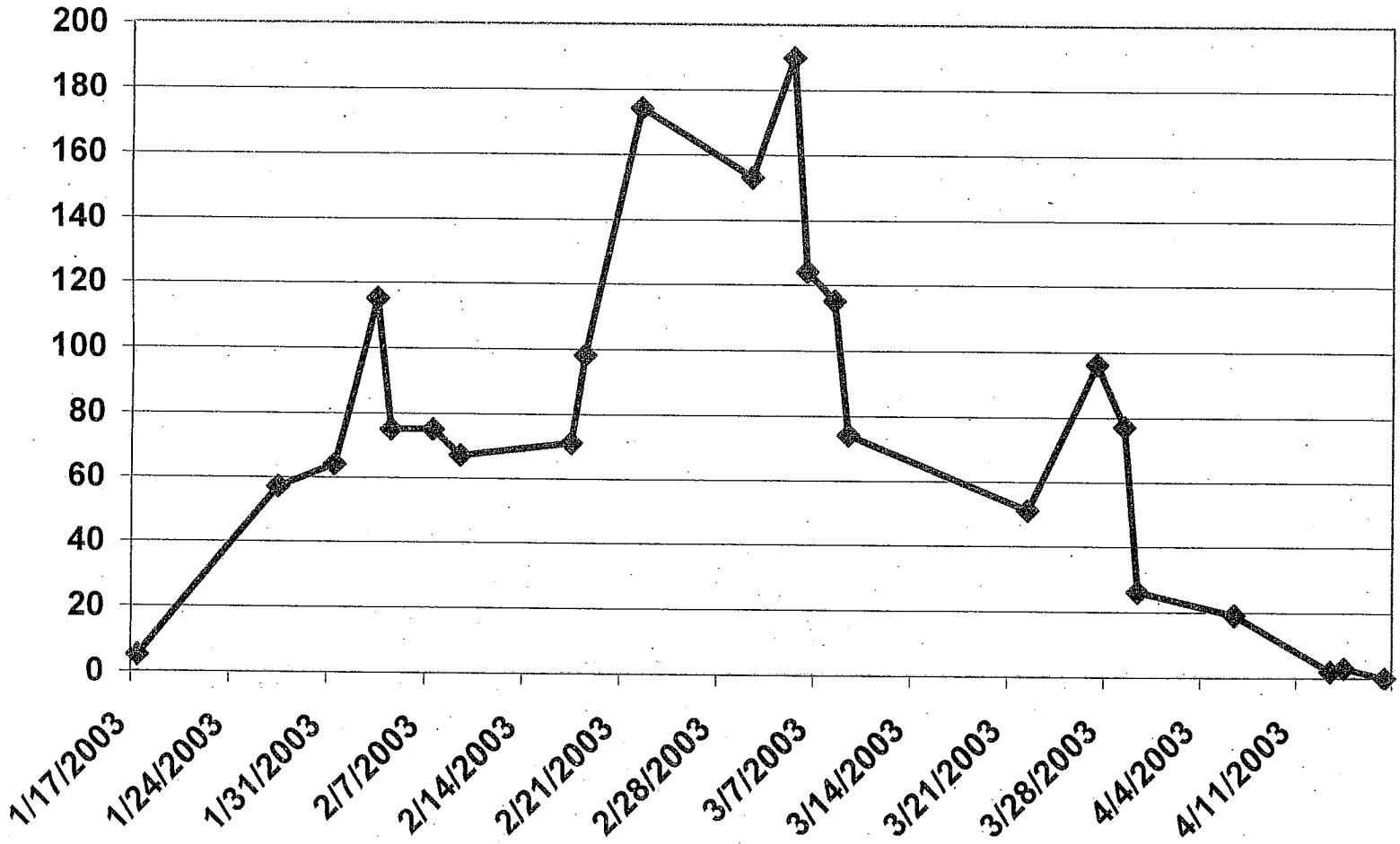


Fig. 4. Survivorship curve for the 2001 cohort of *C. ohlone* at Poliski-Gross site (starting with 180 oviposition burrows

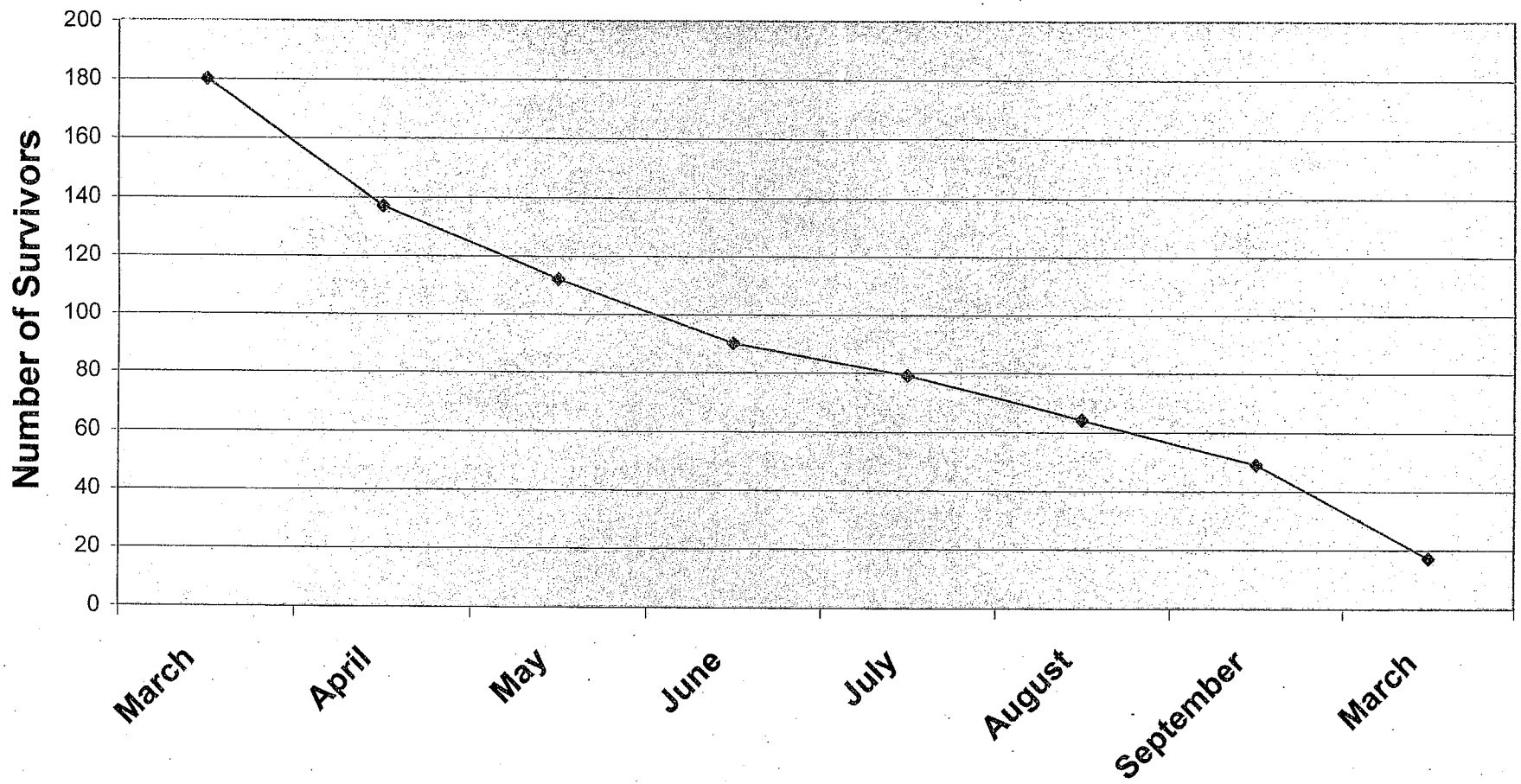


FIG. 5. MEAN EGGS PER WEEK AND TOTAL FECUNDITY AND FEMALE SURVIVAL TIME FOR 3 GROUPS OF FEMALES

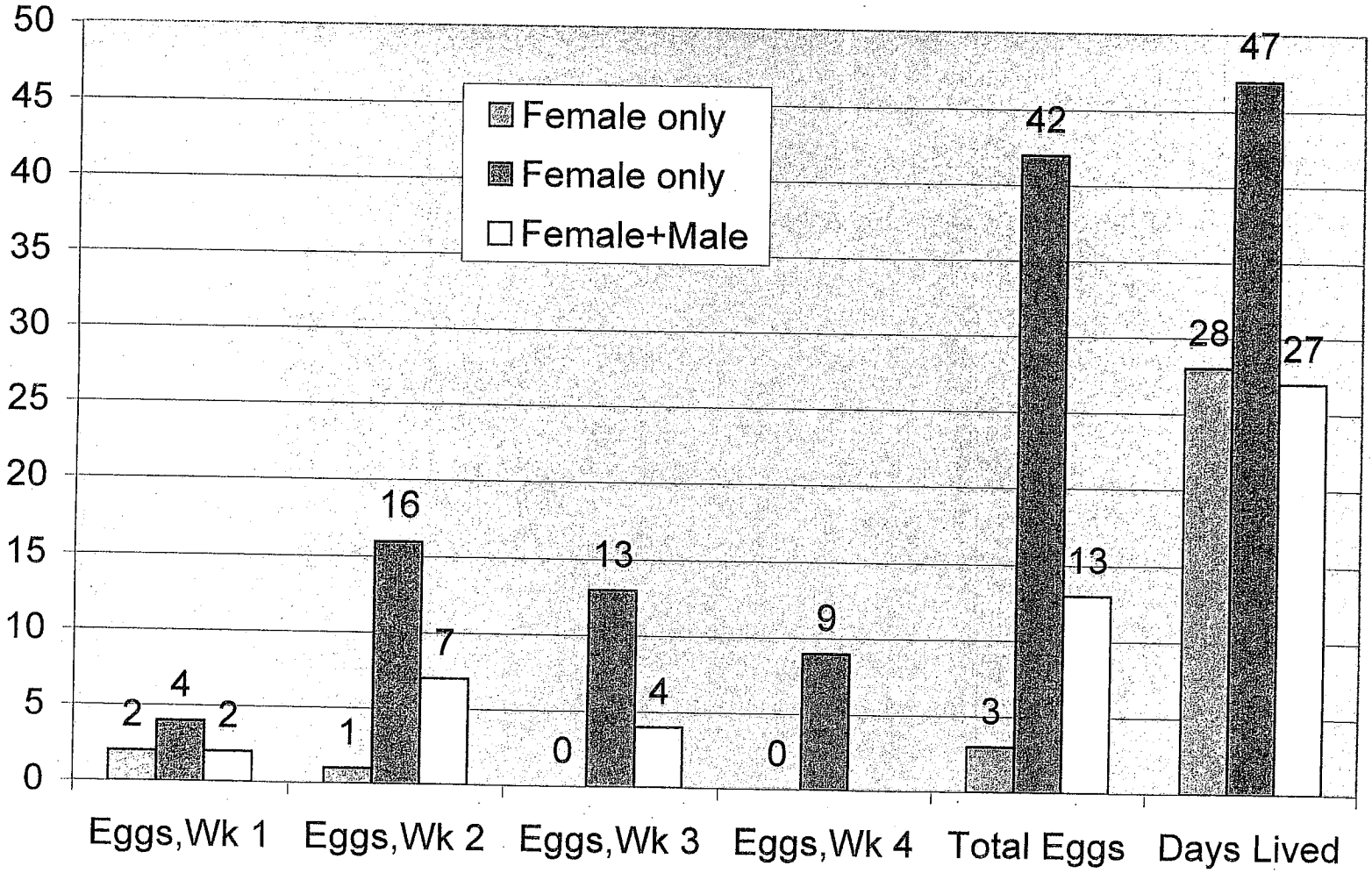
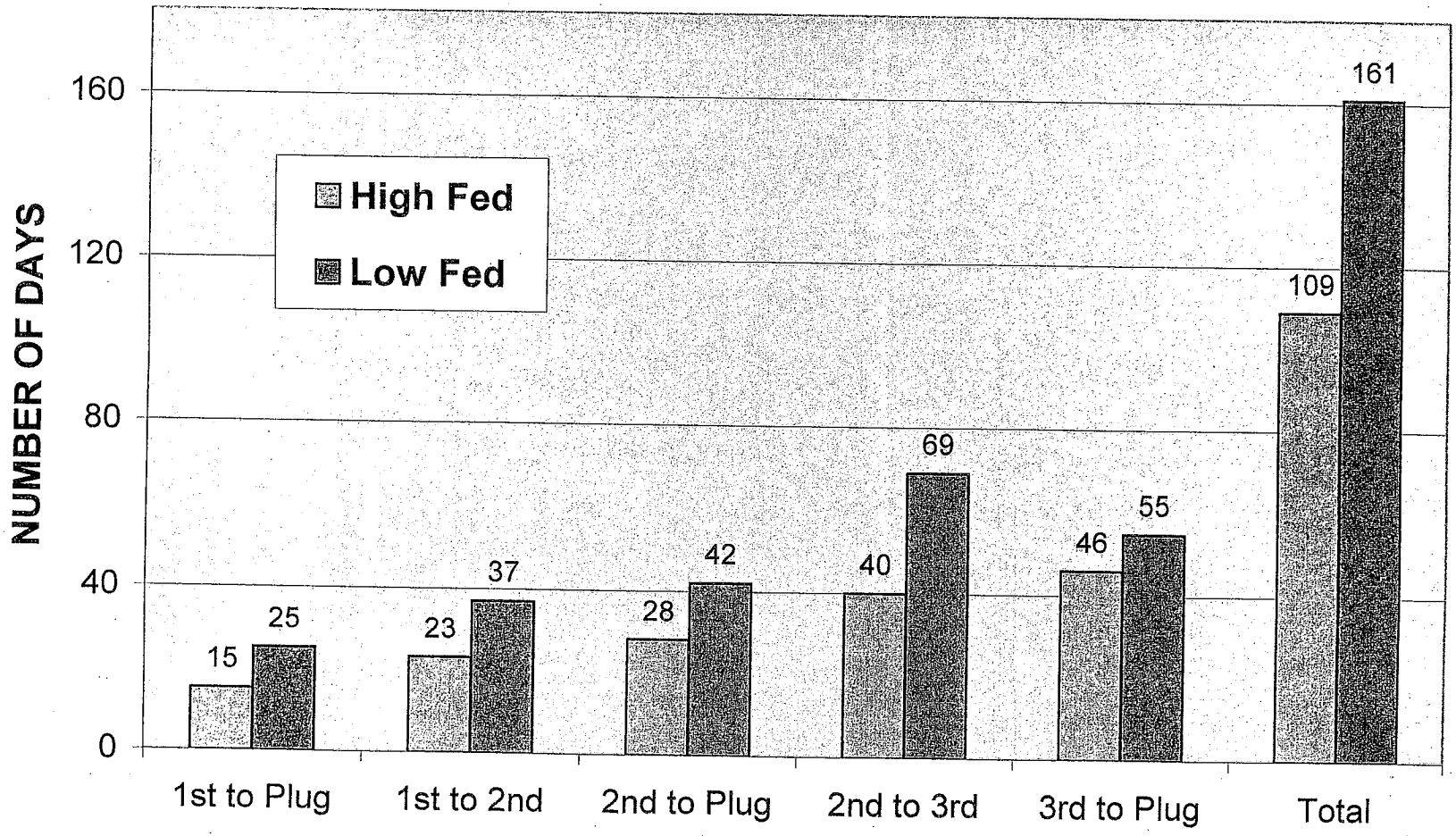


FIG. 6. MEAN LENGTH OF DEVELOPMENT TIME (IN DAYS) FOR LOW AND HIGH FED GROUPS OF THE THREE LARVAL INSTARS OF THE OHLONE TIGER BEETLE



APPENDICES

1. Table and maps of sites in Santa Cruz, San Mateo and Monterey Counties surveyed for Ohlone Tiger Beetles by G. Hayes and others (from petition). Site numbers in left column of table correspond to numbered dots on topographic maps.

	Date name	Time	.les?	Name of Area	Description of Area	eather	#beetles	height of grass	% grass cover	pathways-type, #	Soil type	linear survey.	tal time survey ed
13	4/5 D.N.	11:00 am	no	Baldwin Creek watershed, Smith Grade, Santa Cruz Co.	Mixed annual and perennial grassland with forbs	sunny	*	*	75%	foot paths	clay	.5 km	*
2	3/3 P.G.	3:00 pm	no	Moore Creek watershed, Empire Grade, Santa Cruz Co.	grazed grassland, very wet	sunny, windy, ~60F	na	1"	0-50%	2-4 cow paths	sandy	4 km	1 hr.
2	3/6 P.G.	2:00 pm	yes	*	grazed grassland with flowers	sunny, windy ~60F	1	0"	0%	cow trail- 6' wide	sandy, wet	2 km	1.5 hr.
2	3/6 P.G.	3:30 pm	yes	*	*	*	2	1"	50%	foot path	sandy	2 km	30 min.
2	3/15 P.G.	12:00 pm	yes	*	*	sunny, windy, ~70F	2	2"	*	cow paths	sandy	2 km	30 min.
16	3/25 P.G.	3:00 pm	no	Cave Gulch watershed, Empire Grade, Santa Cruz Co.	ungrazed and grazed coastal prairie	sunny, windy cold, ~60F	na	10"	100%	foot path	clay	4 km	2 hrs.
16	3/26 P.G.	4:00 pm	no	*	*	sunny, windy, ~70F	na	*	*	*	*	*	1.5 hrs.
1	3/24 AC	12:40 pm	no	Winkle Ave., Soquel (previously known location)	ungrazed coastal prairie with diverse native species including *Danthonia californica*	partly cloudy,~60F	na	.5"-2"	50%	dirt road	clayey	700m	20 min.
1	3/27 AC	1:40 pm	yes	*	*	sunny, ~88F	6	*	*	*	*	*	70 min.
1	4/1 AC	11:15 am	yes	*	*	sunny, windy, ~80F	1	*	*	*	*	*	45 min.
1	4/9 AC	4:05 pm	no	*	*	sunny, breezy, ~76F	na	*	*	*	*	*	10 min.
1	4/12 AC	11:30 am	no	*	*	sunny, breezy, ~80F	na	*	*	*	*	350m	30 min.
3	4/1 AC	12:40 on	yes	Marshall Fields, UCSC Empire Grade, Santa Cruz Co. (a previously known location)	ungrazed coastal prairie with diverse native species including *Danthonia californica*	hot, sunny no clouds	27	.5"-1'	50%	footpath	clay	450m	30 min.
17	3/19 AC	4:00 pm	no	Morgan Ranch, Carmel Valley Road Monterey Co.	coastal prairie with many native species	partly cloudy, ~60F	na	.5"-10"	50%	dirt road	clayey	1200m	1.5 hrs.
17	3/30 AC	1:30 pm	no	*	*	*	*	*	*	*	*	*	*
17	4/1 AC	5:15 pm	no	*	*	hazey, ~80F	na	*	*	*	*	*	1.25 hrs.
18	3/24 AC	1:20 pm	no	vacant lot near known Winkle Ave. site, Soquel	coastal prairie with less diversity and more weeds than adjacent reference site	sunny, breezy, ~60F	na	2"	50-100%	dirt road	clayey	225m	20 min.
18	3/27 AC	3:40 pm	no	*	*	sunny, ~88F	*	*	*	*	*	300m	30 min.
18	4/11 AC	11:00 am	no	*	*	sunny, ~80F	*	*	*	*	*	*	*

station (appendix B)	Date name	Time	Beetles?	Name of Area	Description of Area	weather	#beetles	height of grass	% grass cover	pathways-type, #	Soil type	linear arc. surveyed	total time survey ed
6	3/6 J.P.	12:15 pm	no	Cascade Ranch, S. San Mateo Co. "Coppock Pond", grazed area, diversity of grasses, native forbs, some bare areas----- trail to ocean through very nice native moist prairie	grassland hills adjacent to reservoir grassland flat trail to ocean	sunny cool windy	na	6"-12"	95%	dirt roads	clay loam	1800m	1 hr.
6	3/12 J.P.	1:30 pm	no	"	see above	cloudy cool windy	na	"	"	"	"	2400m	1 hr.
5	3/3 J.P.	1:45 pm	no	Pogonip Park, City of Santa Cruz	flat hilltop grassland near clubhouse	hazy, cool breezy	na	3"-6"	95%	footpaths, horse trails	clay loam	3700m	1 hr.
5	3/17 J.P.	2:15 pm	yes	"	clubhouse area and upper area by Coolidge Drive	sunny & warm	7	"	"	"	"	2800m	1 hr.
5	3/26 J.P.	2:00 pm	no	"	"	sunny warm breezy	na	"	"	"	"	3200m	1 hr.
7	3/27 J.P.	12:00 pm	no	New Brighton State Beach, Santa Cruz Co	grassland mostly flat	sunny warm	na	6"	95%	dirt roads footpaths	clay	1200m	45 min.
8	4/2 J.P	11:30 am	no	Garrapata State Park, Monterey Co.	Ridge top grassland hillside, coastal scrub canyon, redwoods	sunny warm windy	na	6"	99%	footpaths	rocky claycy	11,000m	2 hrs.
9	3/17 J.P.	11:00 am	no	Bel Mar Development, Santa Cruz Co.	oak woodland above Hwy 1	sunny warm	na	6"	10%	dirt roads	sandy clay	1500m	30 min.
9	3/26 J.P.	12:00 pm	no	"	"	"	"	"	"	"	"	300m	15 min.
10	3/26 J.P.	1:00 pm	no	College Drive, Soquel	small pasture next to creek	sunny warm	na	24"-36"	100%	none	clay	300m	15 min.
11	3/17 J.P.	11:30 am	no	San Andreas Road, Santa Cruz Co.	oak grassland with cows, 2 ridges and valley	sunny warm	na	3"-6"	99%	cow paths	clay	1200m	45min.
11	3/26 J.P.	12:30 pm	no	"	"	"	"	"	"	"	"	1000m	40min.
11	3/27 J.P.	11:00 am	no	"	"	"	"	"	"	"	"	1200m	45min.
12	3/12 D.N.	2:00 pm	no	Above Bituminous Quarry, Smith Grade, Santa Cruz Co.	*Danthonia californica, Bromus carinatus* grassland	partly cloudy, some wind	na	6"-1'	50%	1 foot path	clay	1/10km	10min.
13	3/12 D.N.	2:15 pm	no	Baldwin Creek watershed, Smith Grade, Santa Cruz Co.	Mixed annual and perennial grassland with forbs	"	"	"	75%	2 foot paths	clay	2/10km	30min.
13	3/12 D.N.	2:45 pm	no	Baldwin Creek watershed, Smith Grade, Santa Cruz Co.	"	"	"	"	"	3 foot paths	"	2/10km	30min.
14	3/12 D.N.	3:30 pm	no	Baldwin Creek watershed, Smith Grade, S.CR.	Non-native grassland bordered by shrubs and mixed evergreen forest	"	"	"	"	1 dirt road	clay and sand	.5 km	1 hr.
15	3/16 D.N.	2:00 pm	no	Laguna Creek watershed, Smith Grade, Santa Cruz Co.	*Danthonia californica* and annual grass prairie	sunny	"	"	100%	1 dirt road	sandy clay	1/10 km	20 min.
13	4/2 D.N.	12:00 pm	no	Baldwin Creek watershed, Smith Grade, S.CR	Mixed annual and perennial grassland with forbs	sunny	"	"	75%	foot paths	clay	.5 km	1/2 hr.

map locations (appendix B)	Date name	Time	Beetles?	Name of Area	Description of Area	weather	#beetles	height of grass	% grass cover	pathways-type, #	Soil type	linea. surveyed	total time survey ed
19	3/28 AC	2:30 pm	no	North side of Schwan Lake, Live Oak Avenue, City of Live Oak	coastal prairie with french broom in patches	sunny, ~82F	na	2"-5"	50%	footpaths	claycy	850 m	45 min.
19	4/21 AC	2:30 pm	no	"	"	synny, ~80F	"	"	"	"	"	"	30 min.
20	3/8 G	2:00 pm	no	Arana Gulch Greenbelt Land, City of Santa Cruz N. of Yacht Harbor	coastal prairie with good patches of Danthonia/Stipa, also weedy areas	sunny, breezy 60F	"	4"-1'	70-100%	footpaths	claycy	1500m	1 hr.
20	3/21 G	12:30 pm	"	"	"	sunny, ~60F	"	"	"	"	"	"	"
20	4/10 G	2:00 pm	"	"	"	sunny, breezy 70F	"	"	"	"	"	"	1.5 hr.
21	3/11 G	3:30 pm	no	DeLaveaga Park, City of Santa Cruz	native grass dominated coastal prairie surrounded by mixed oak woodland	mostly sunny, breezy, 65F	"	3-5"	0-80%	wide, bare areas, footpaths, roads	clay and sandy loam	4000m	3 hrs.
21	3/17 G	2:00 pm	no	"	"	sunny, 70F	"	"	"	"	"	"	2 hrs.
21	4/14 G	3:00 pm	"	"	"	sunny,~70F	"	"	"	"	"	"	3 hrs.
6	3/12 G.	3 pm	no	Cascade Ranch, S. San Mateo Co.	"Coppock Pond", grazed area, diversity of grasses, native forbs, some bare areas----- trail to ocean through very nice native moist prairie	cool, overcast, breezy	na	Pond= 3" Ocean trail=6"-1'	Pond=50 % Ocean=8 5%	Pond=cow, foot trails Ocean=road, foot trail	sandy clay loam	2000m	2 hrs.
6	4/6 G	2:30 pm	no	"	"	sunny, windy 60F	"	4-12"	"	"	"	"	30 min.

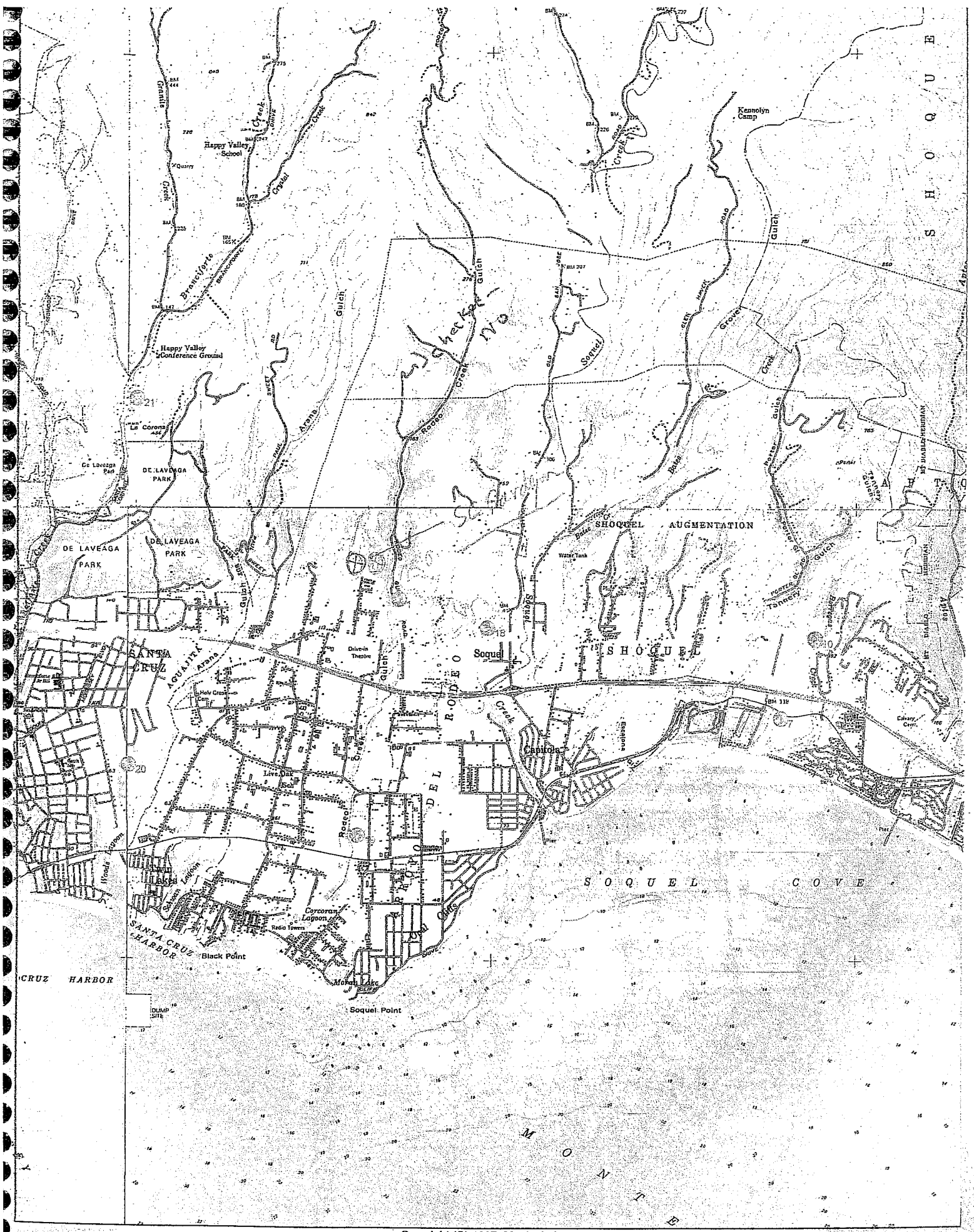
Abreviations:

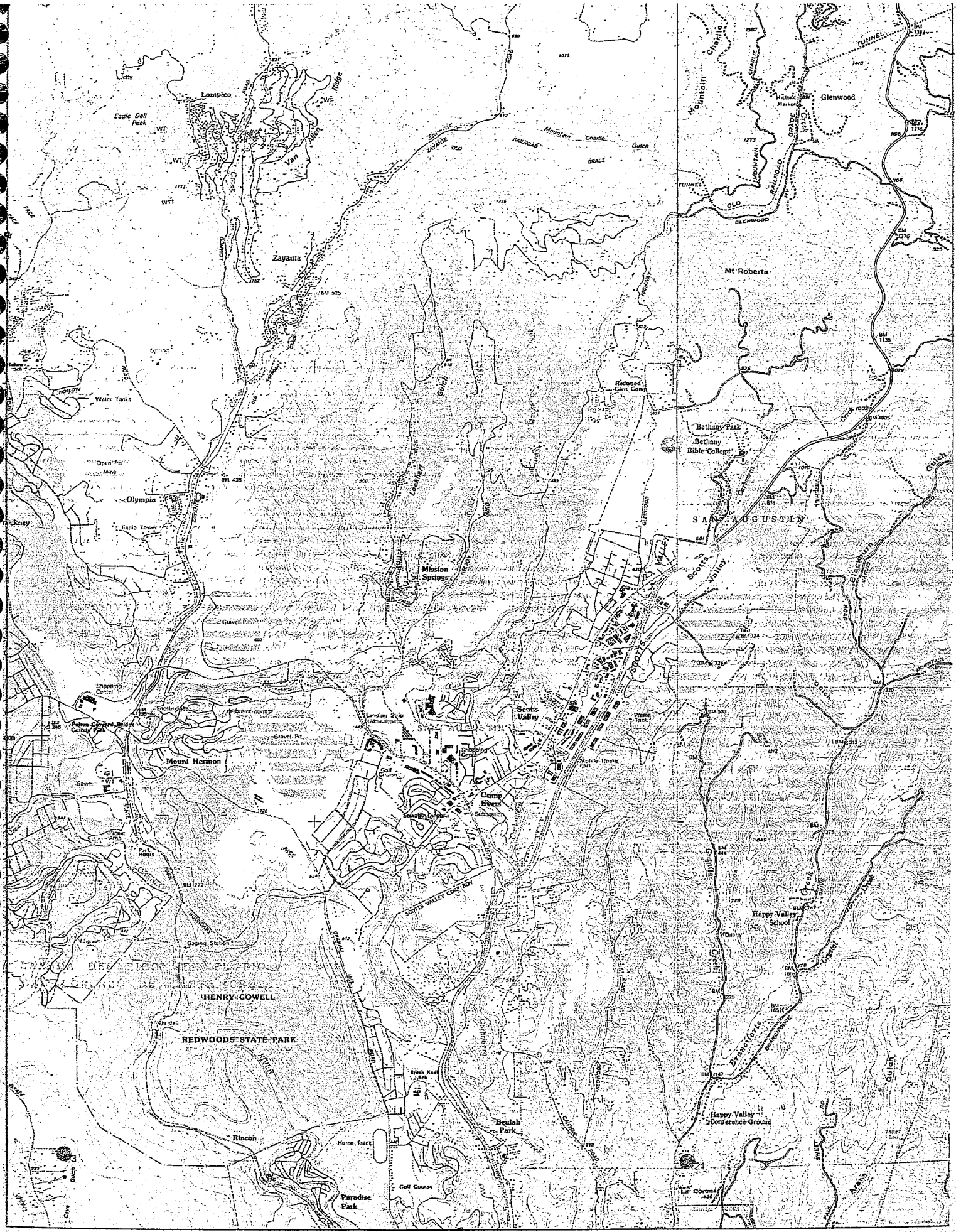
JP = John Pritchard
PG = Polly Goldman
DN= Dylan Neubauer
AC = Alice Cascorbi
G = Grey

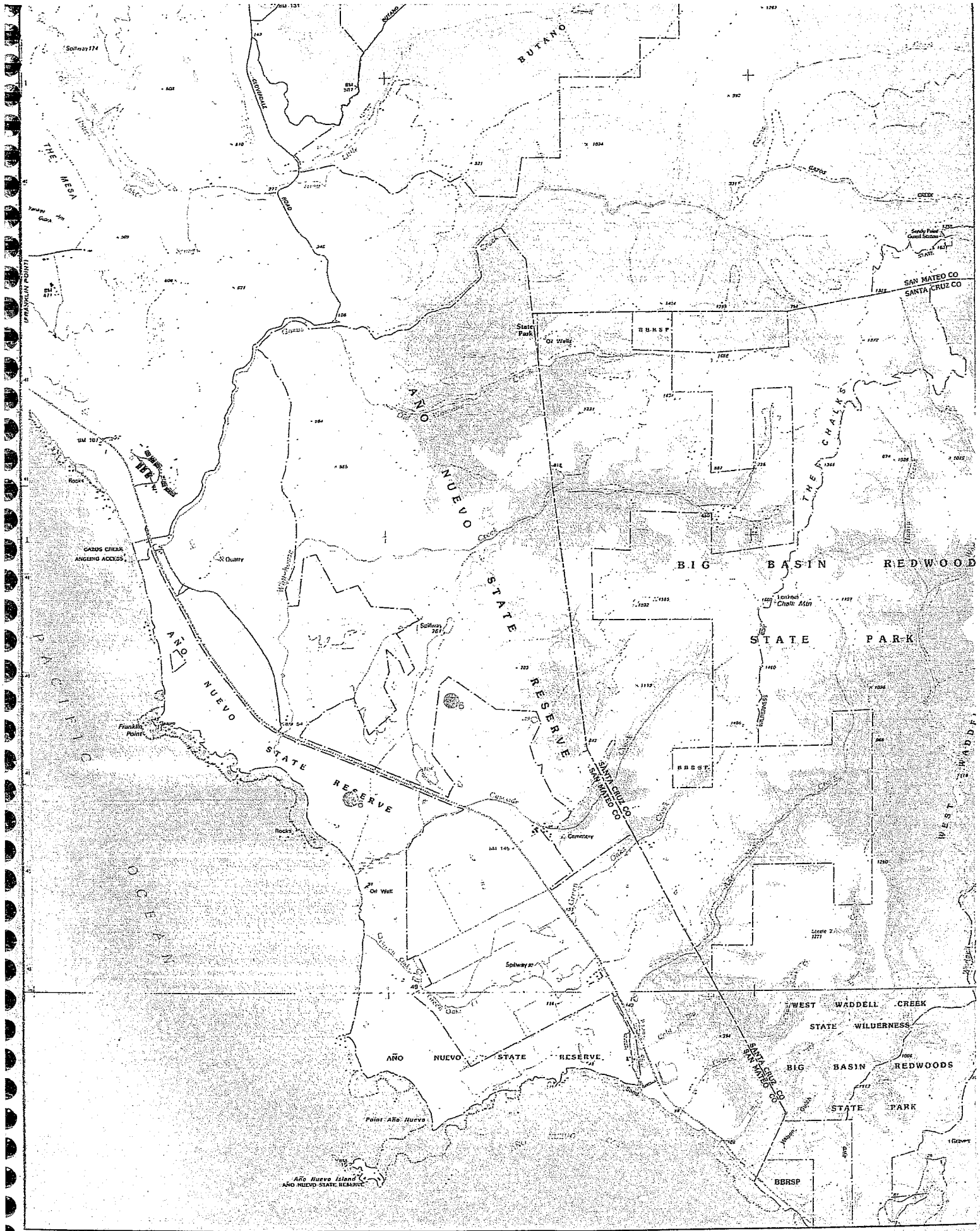
" = inches
' = foot

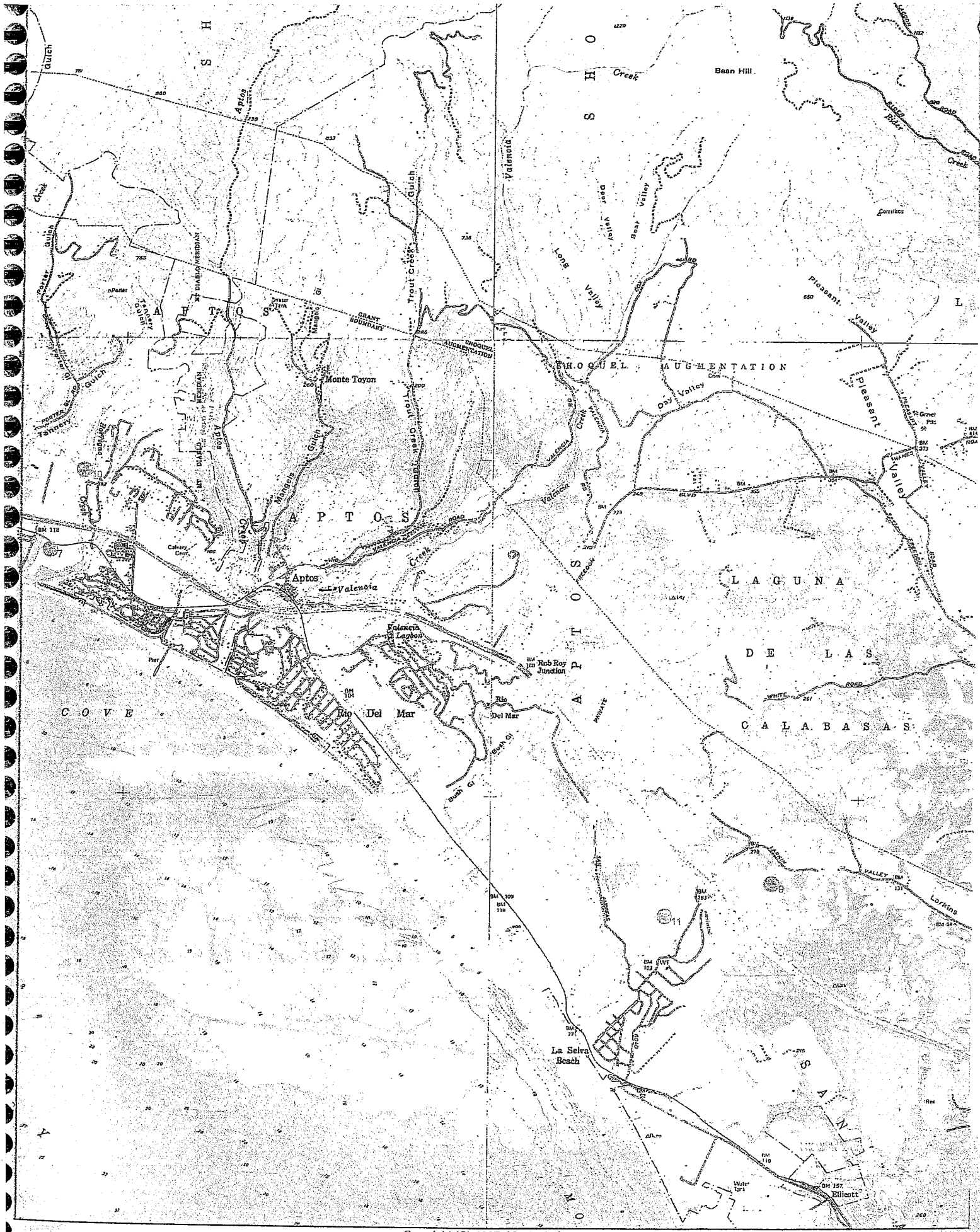
hr (s) = hour(s)
min = minutes

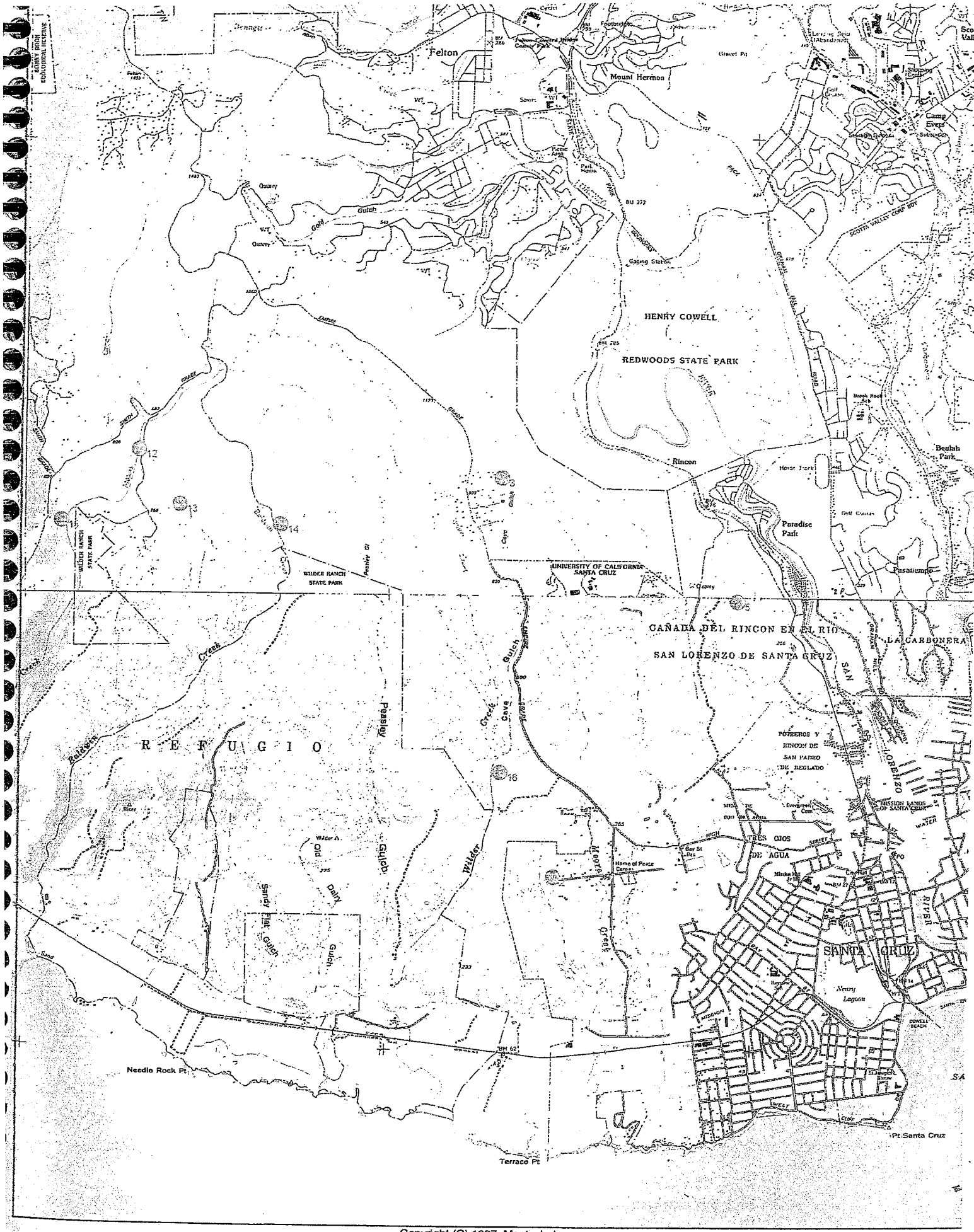
F = Degrees Farenheit



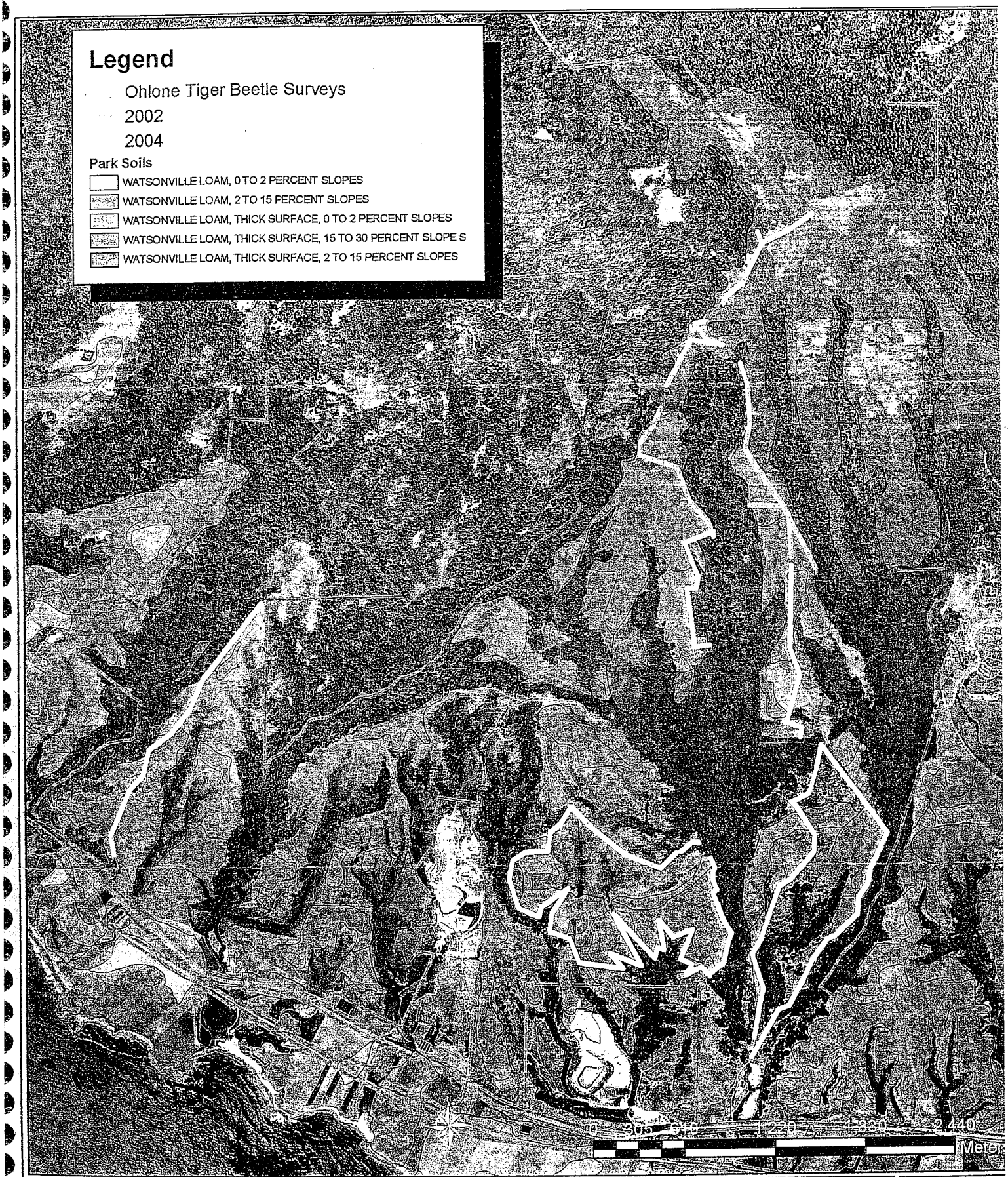








2. Map of sites surveyed at Wilder Ranch State Park by Tim Hyland in 2002 and 2004



Date: 3/4/03

Projection:
State Plane, Zone 10, Meters
NAD83

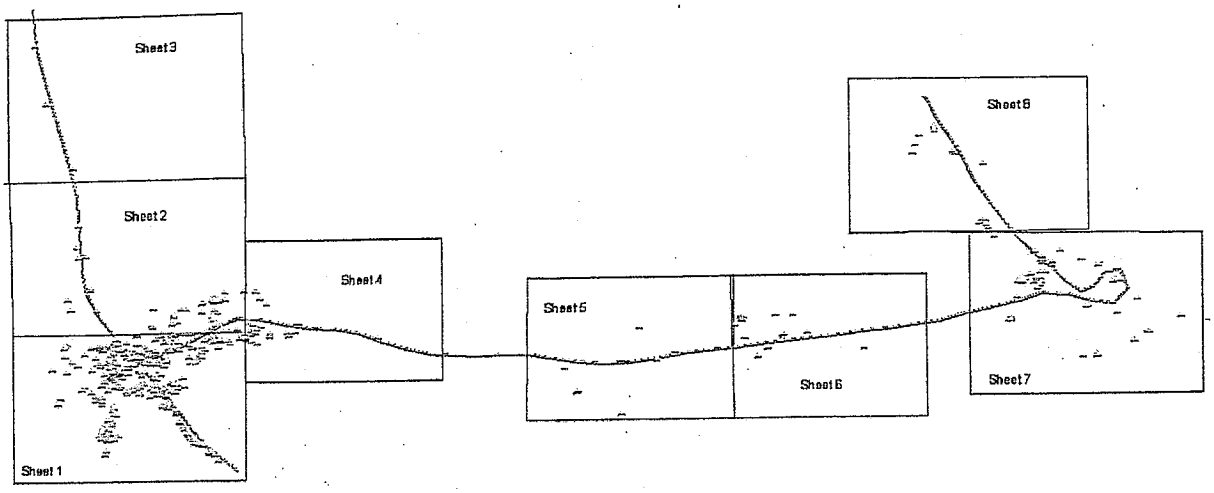
Source:

PARK:
Wilder Ranch, Graywhale Aquisition
PROJECT:
Ohlone Tiger Beetle Surveys 2004

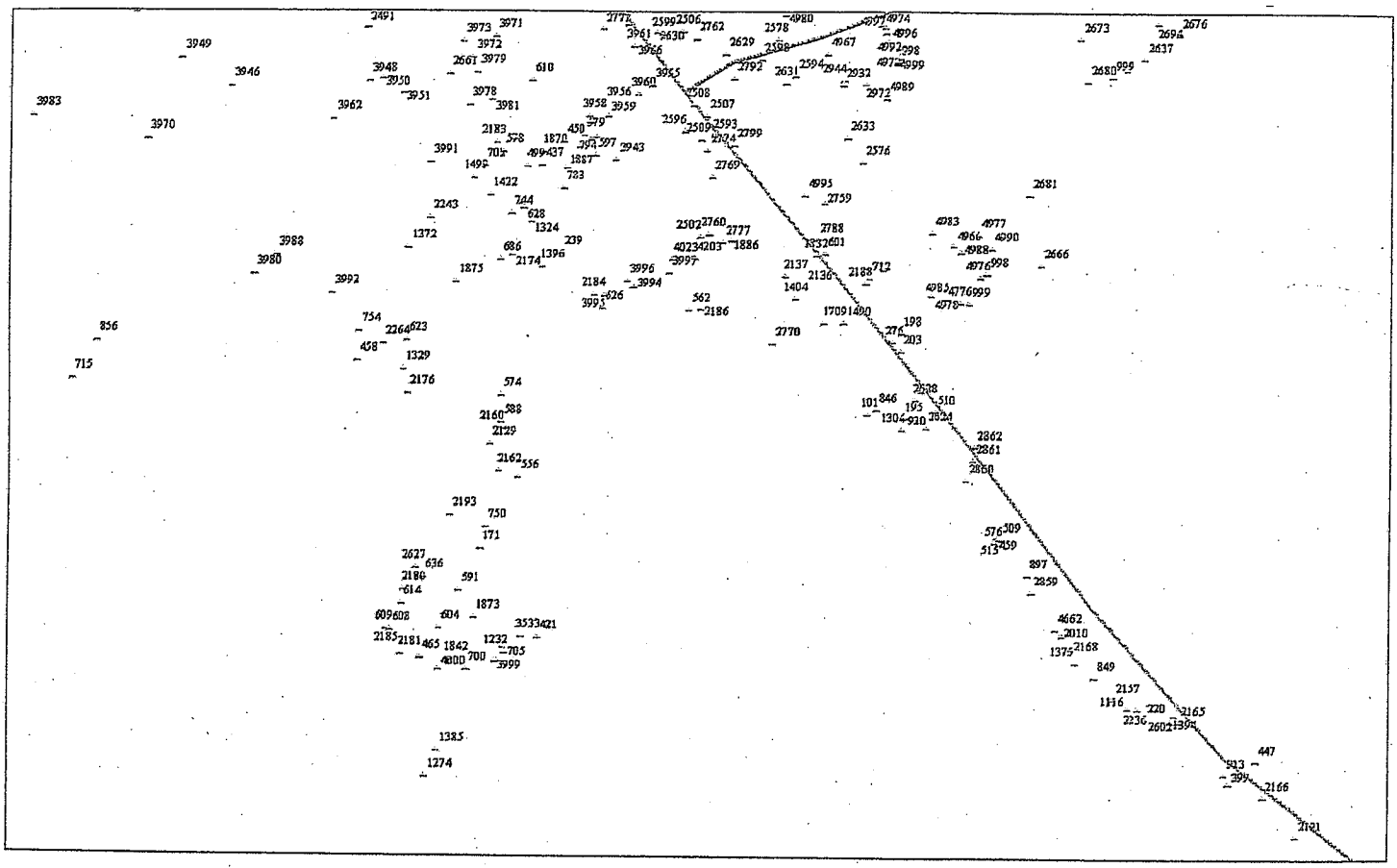
NOTES: ALL OF THESE SITES WERE SURVEYED REPEATEDLY EXCEPT THE ONE WE

RESOURCE
SECTION
SANTA CRUZ
DISTRICT
303 Big Trees
Park Drive

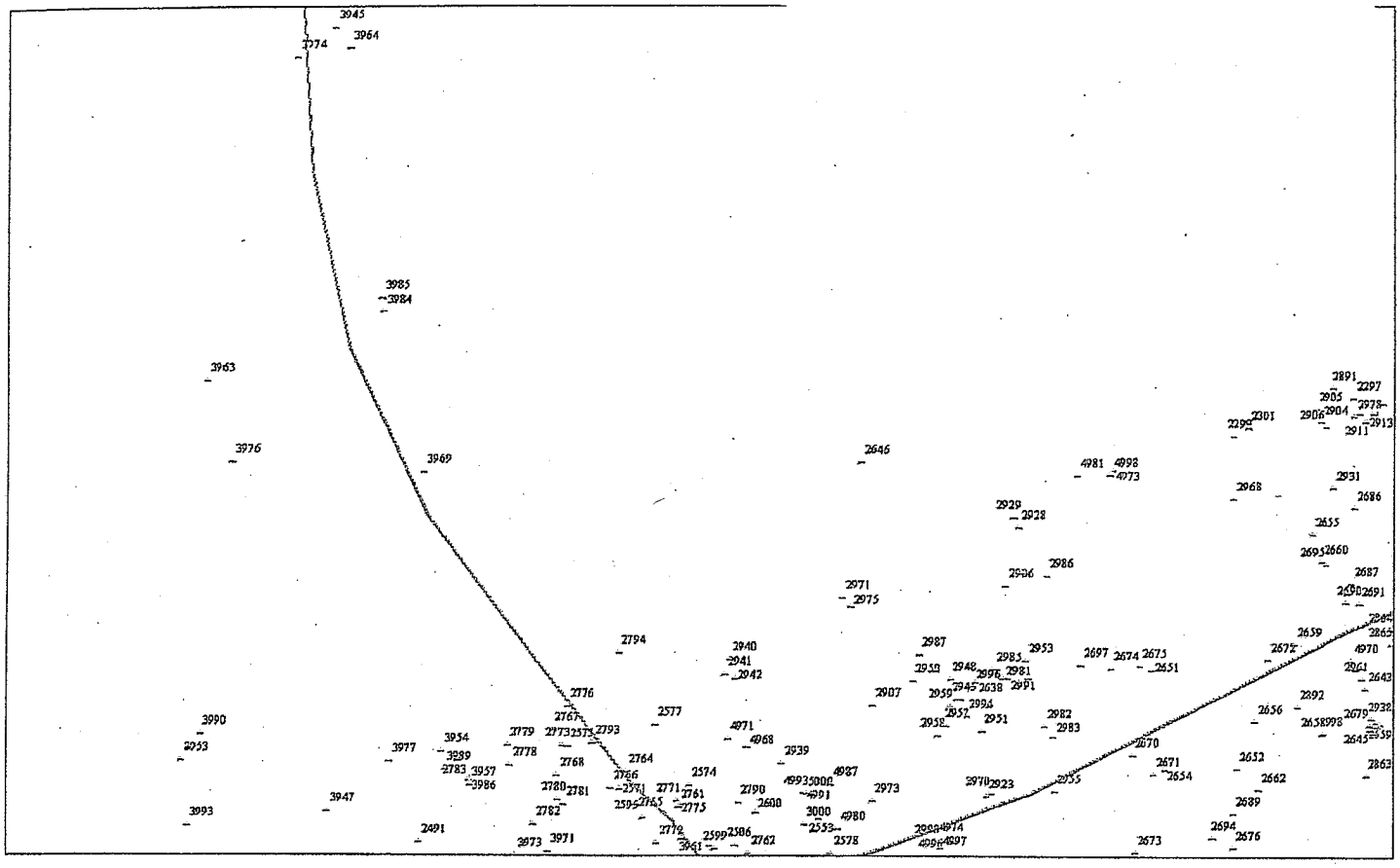
3. Maps showing distribution of larval burrows (with metal tag numbers) at OTB sites in 2003. Scotts Valley, Gray Whale, Santa Cruz Gardens (=Soquel), Poliski-Gross, and Marshall Fields



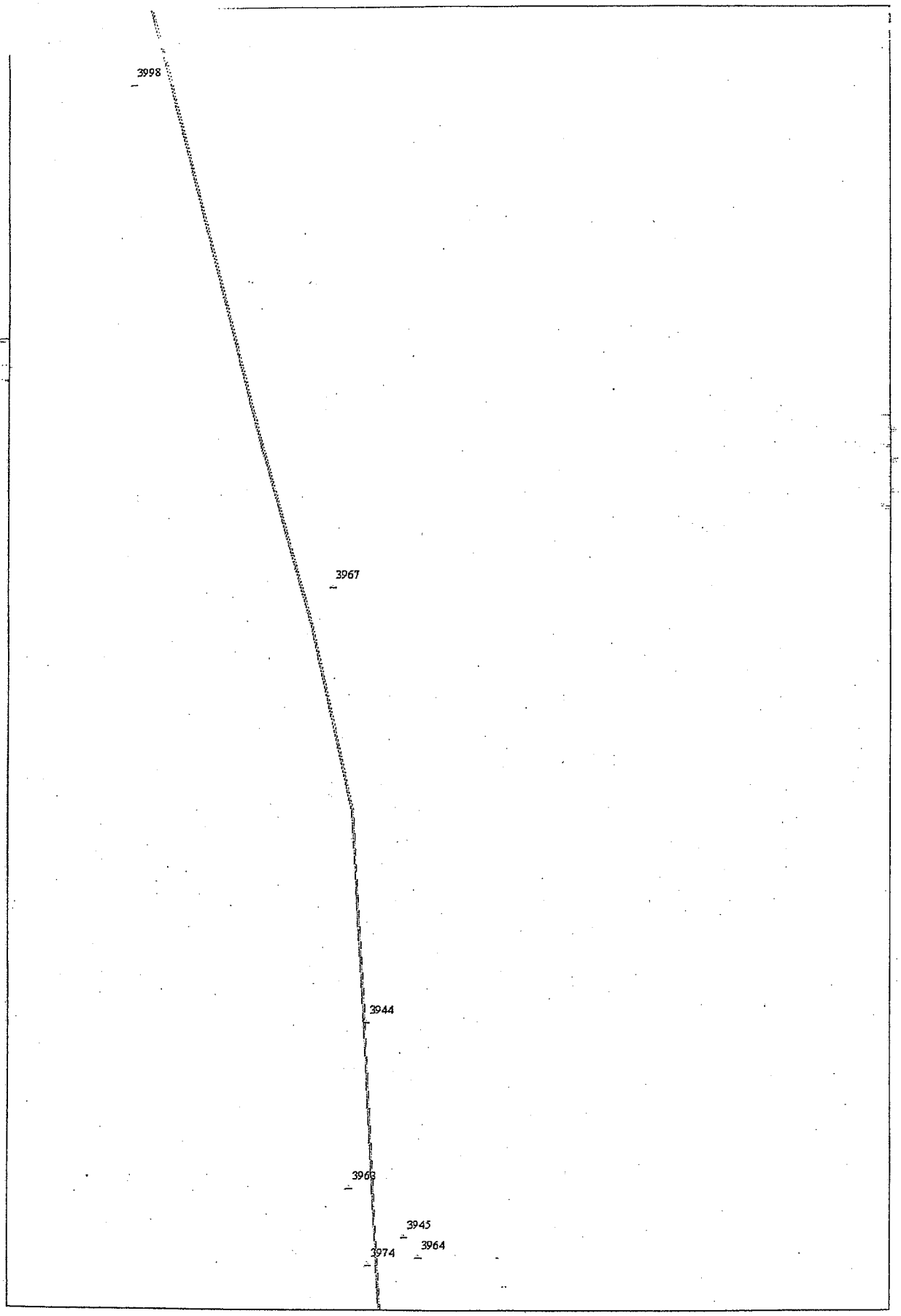
Ohlone Tiger Beetle Study - Scotts Valley - Glenwood Site
Burrows Identified in 2003 - KEY



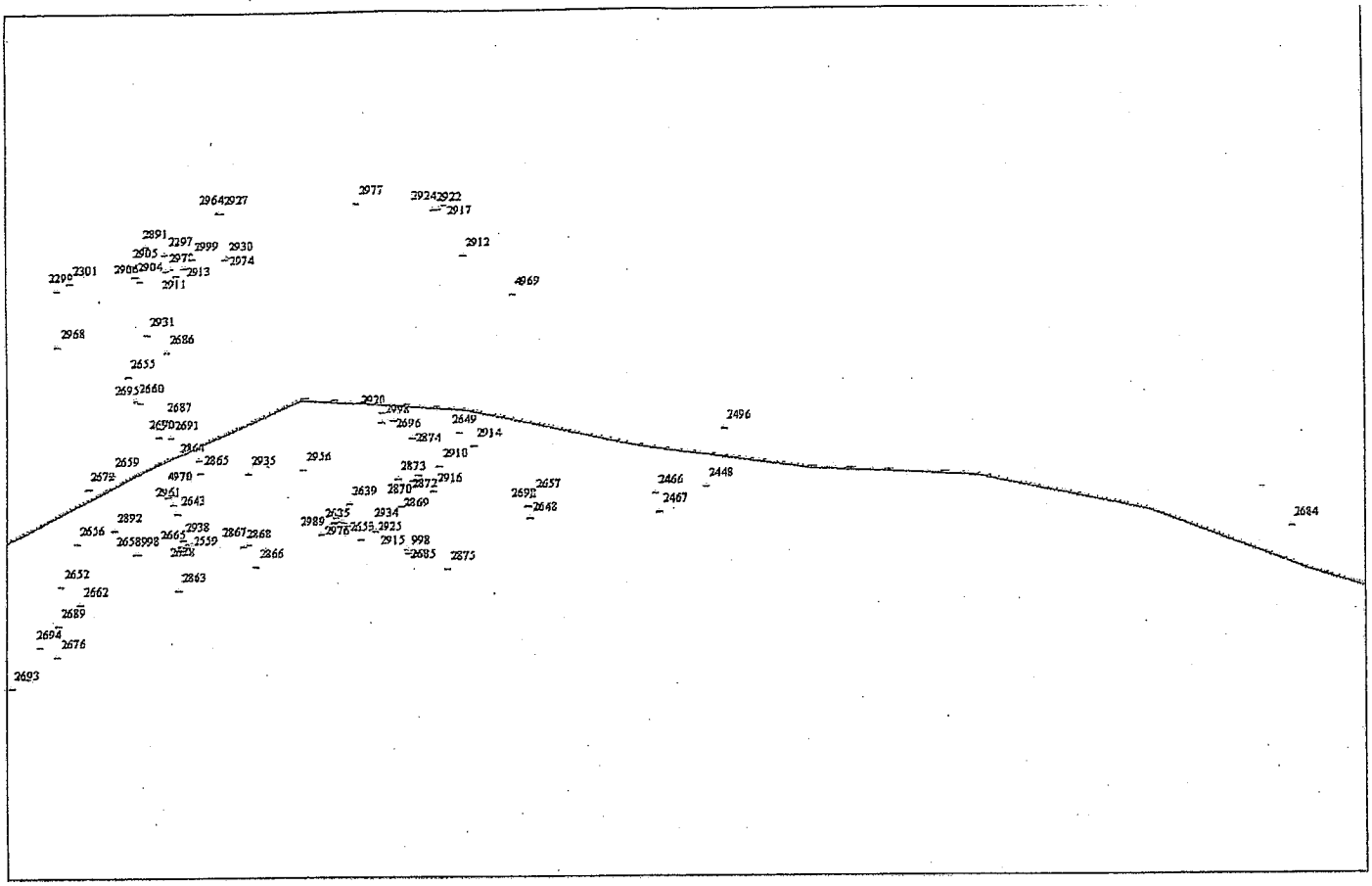
Ohlone Tiger Beetle Study - Scotts Valley - Glenwood Site
Burrows Identified in 2003 - Sheet 1



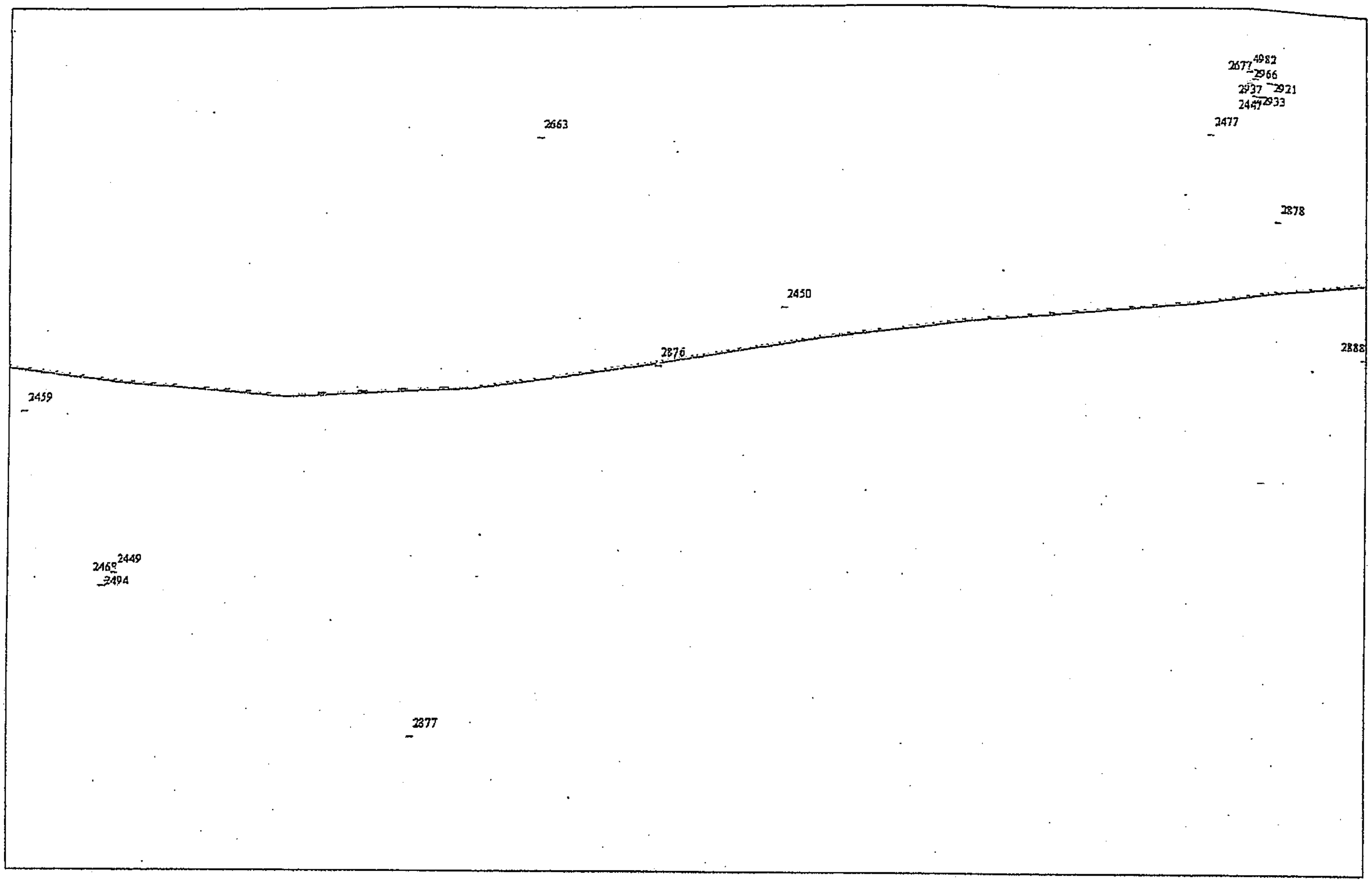
Ohlone Tiger Beetle Study - Scotts Valley - Glenwood Site
Burrows Identified in 2003 - Sheet 2



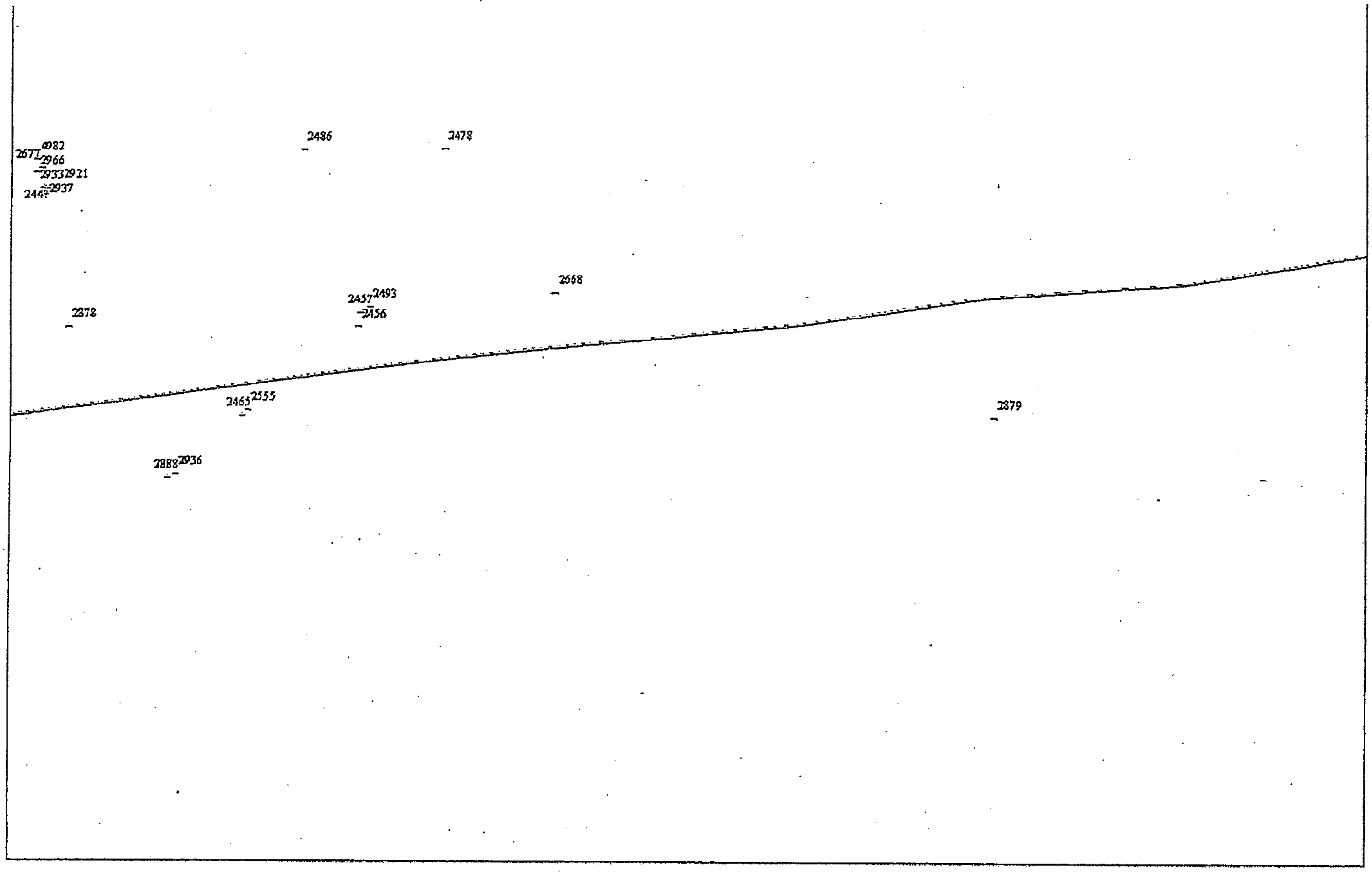
Ohlone Tiger Beetle Study - Scotts Valley - Glenwood Site
Burrows Identified in 2003 - Sheet 3



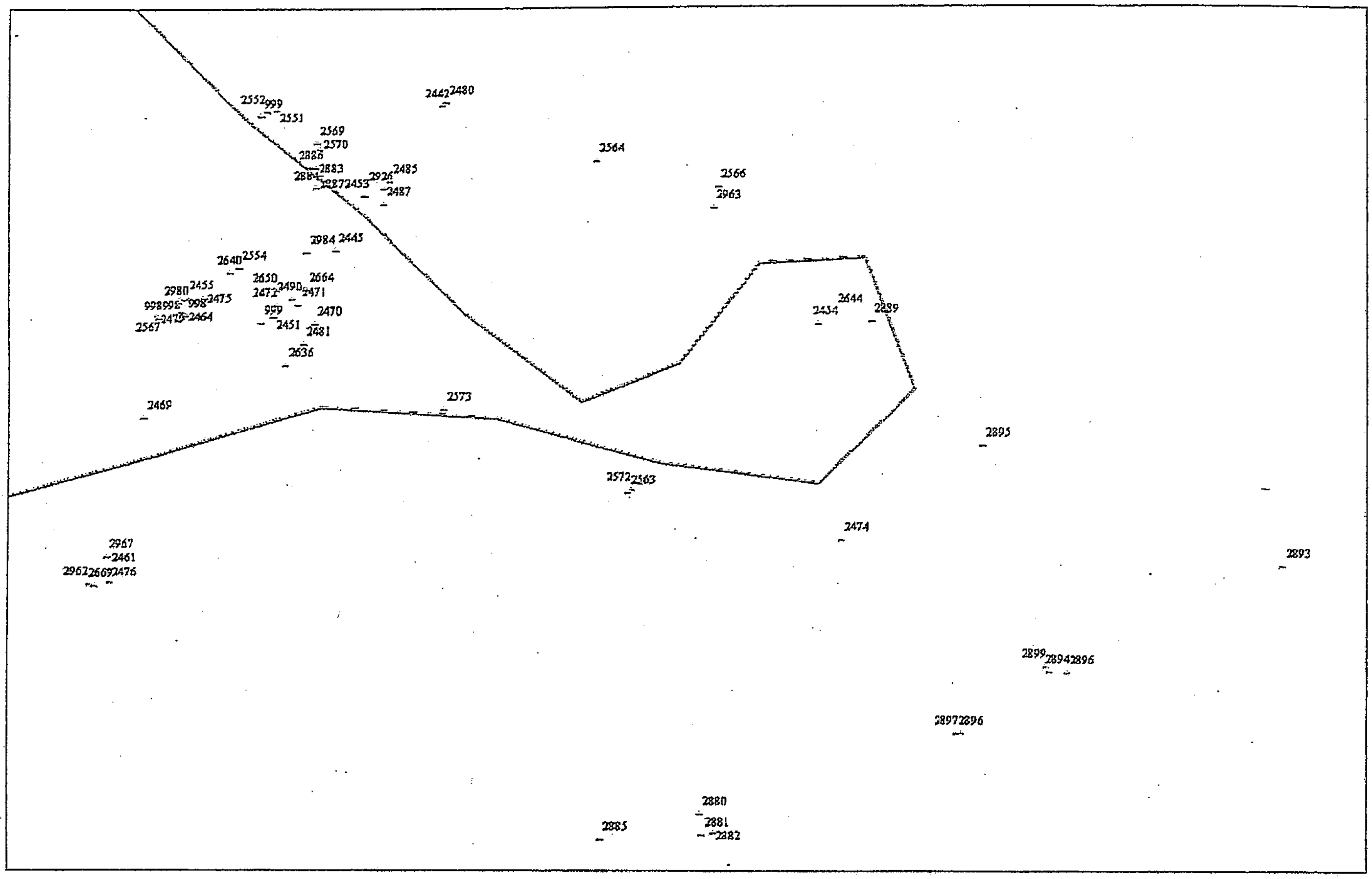
Oakes Tiger Beetle Study - Scotts Valley - Glenwood Site
Burrows Identified in 2003 - Sheet 4



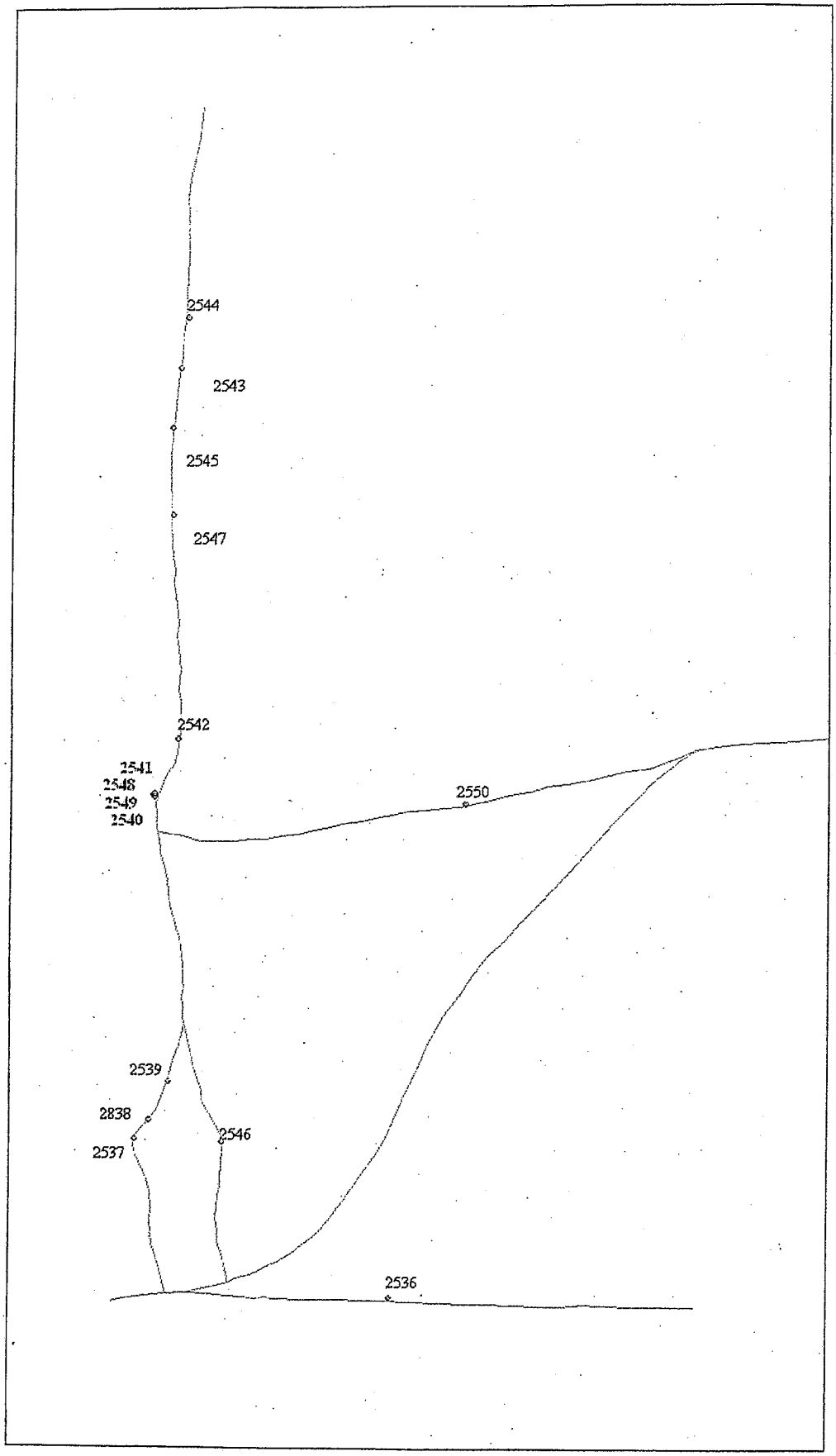
Ohlone Tiger Beetle Study - Scotts Valley - Glenwood Site
Burrows Identified in 2003 - Sheet 15



Ohlone Tiger Beetle Study - Scotts Valley - Glenwood Site
Burrows Identified in 2003 - Sheet 6

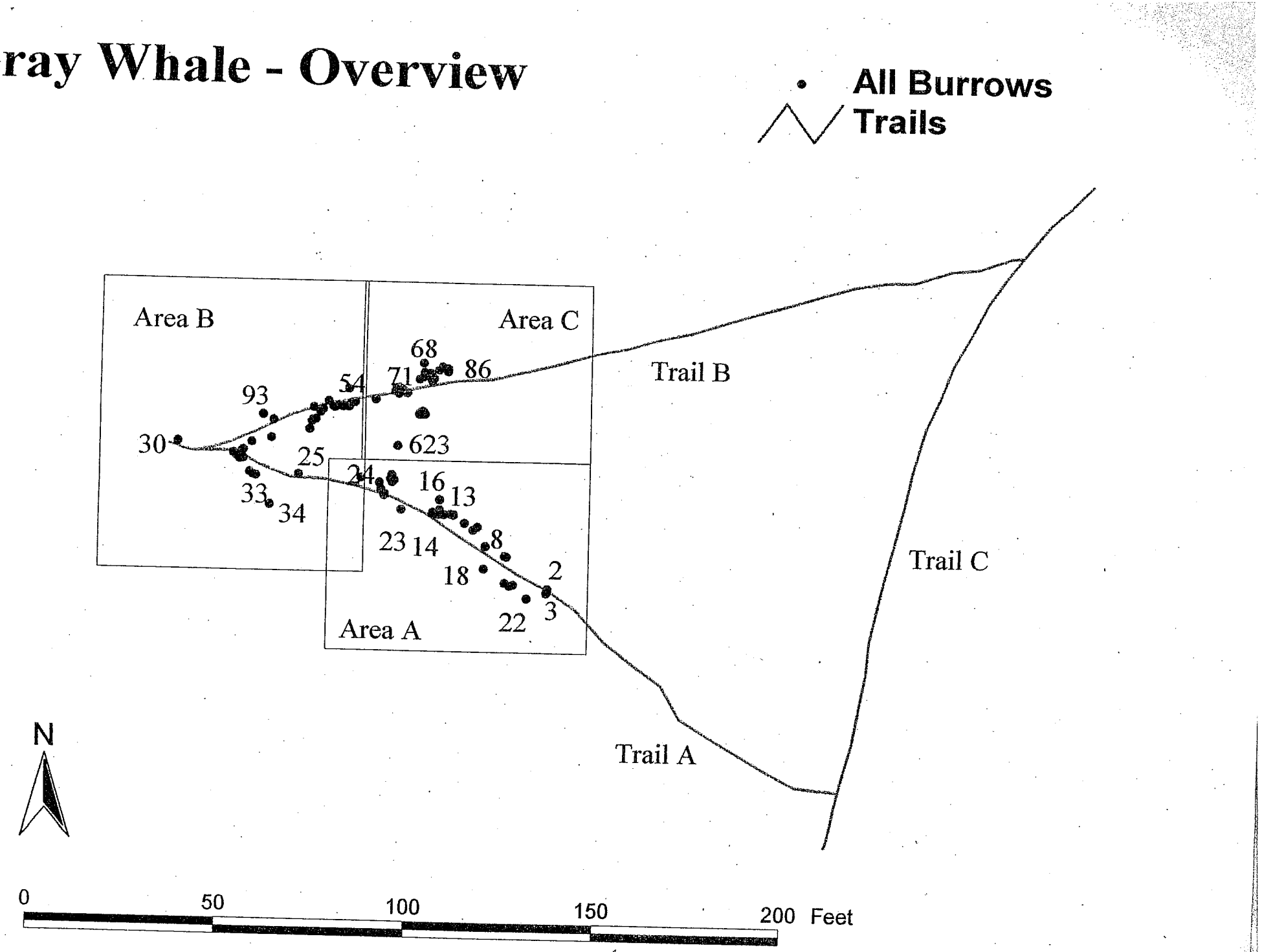


Ohlone Tiger Beetle Study - Scotts Valley - Glenwood Site
Burrows Identified in 2003 - Sheet 7

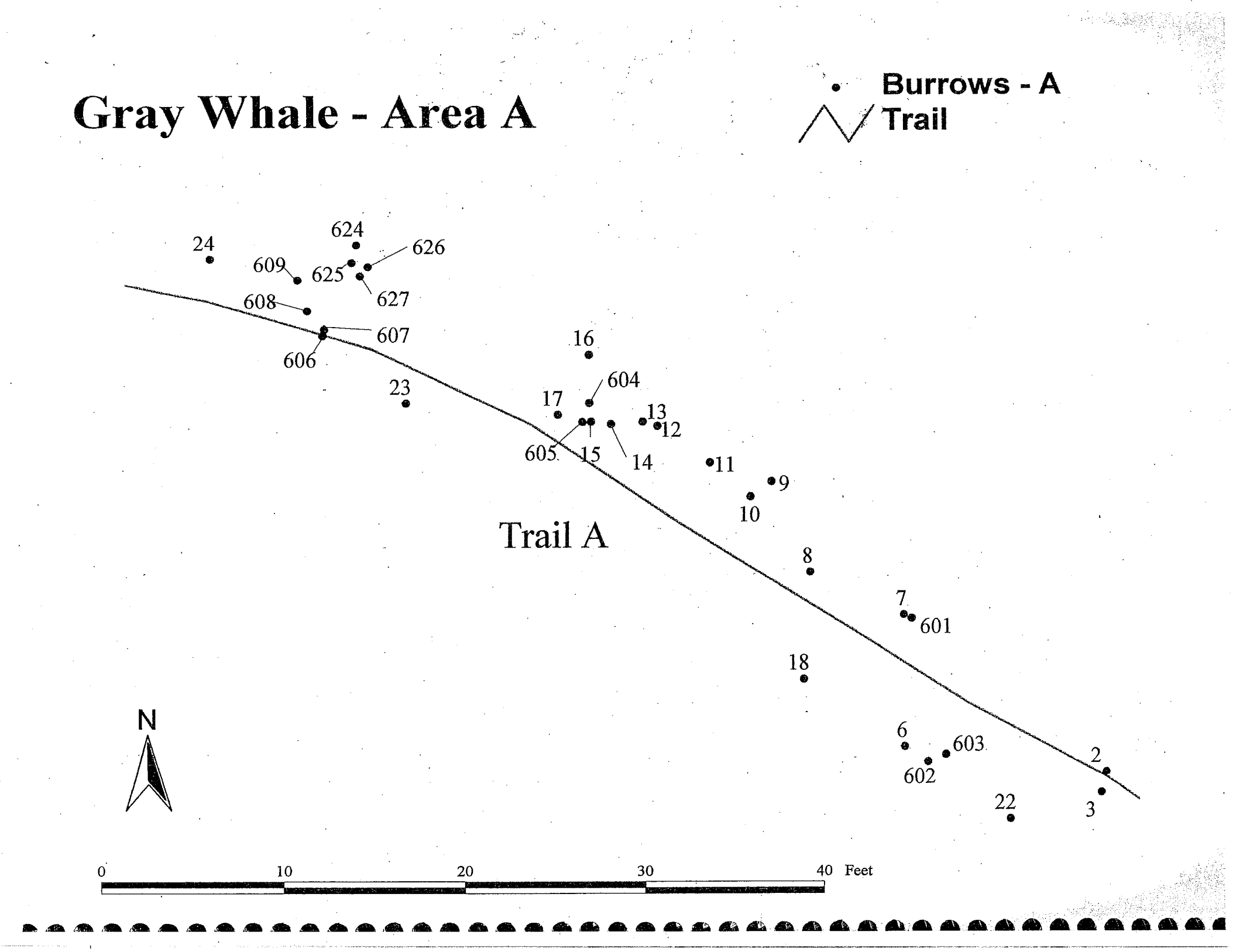


Ohlone Tiger Beetle Study - UCSC - Area A
Burrows Identified in 2003 - All

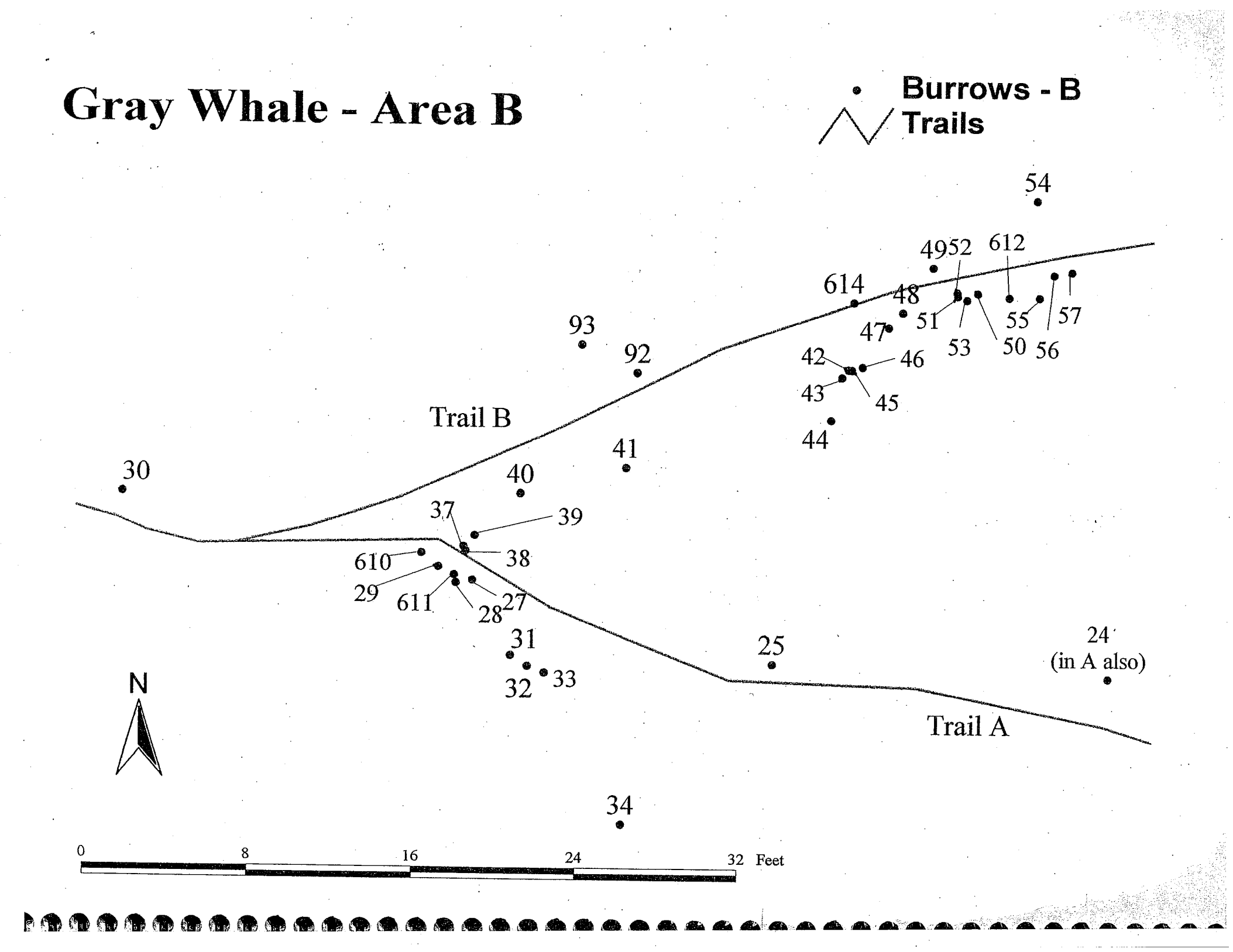
Gray Whale - Overview



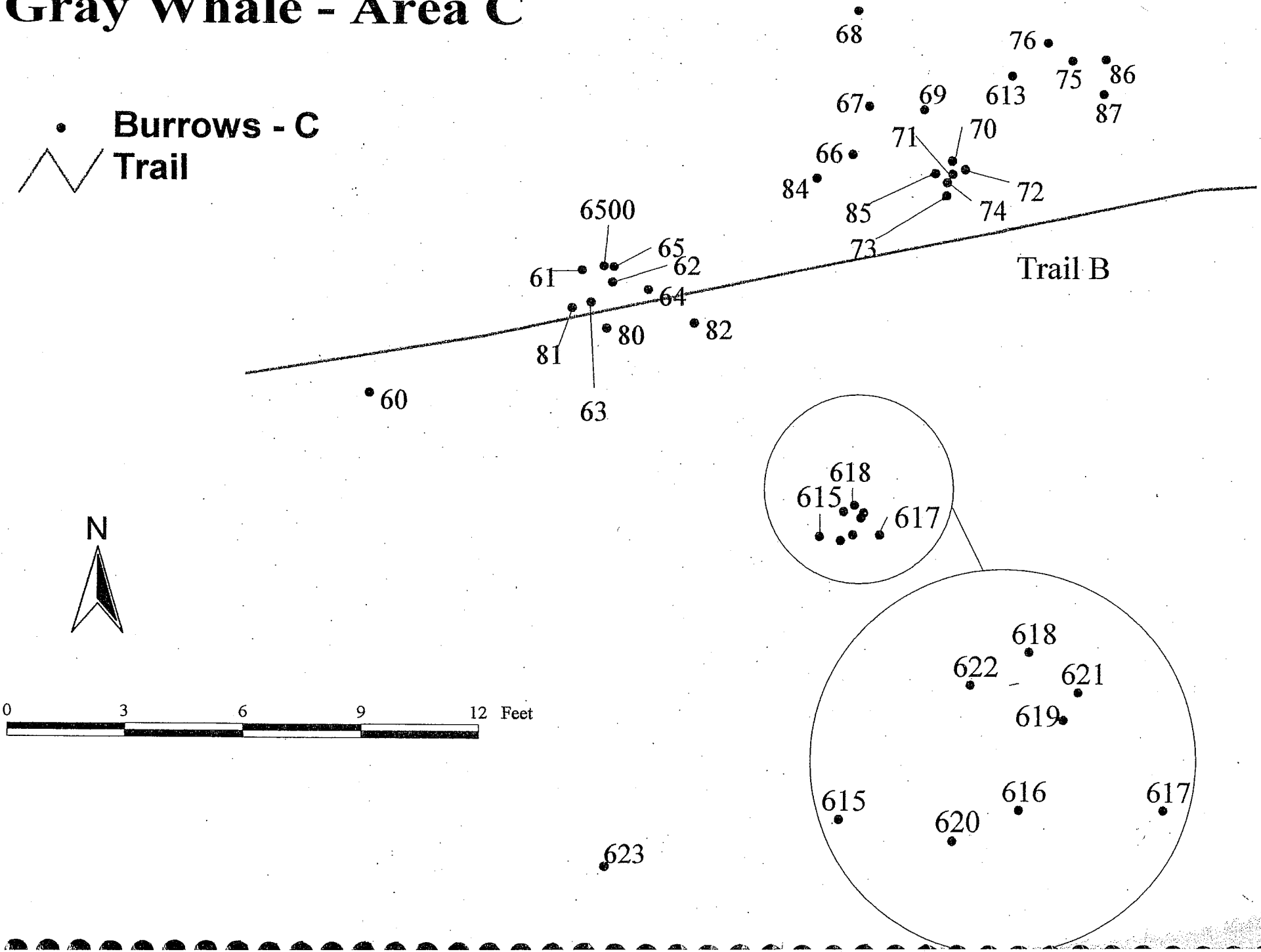
Gray Whale - Area A



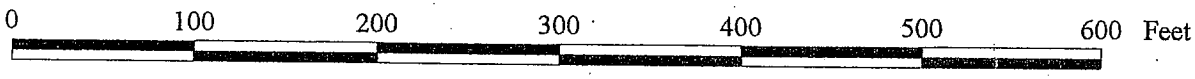
Gray Whale - Area B



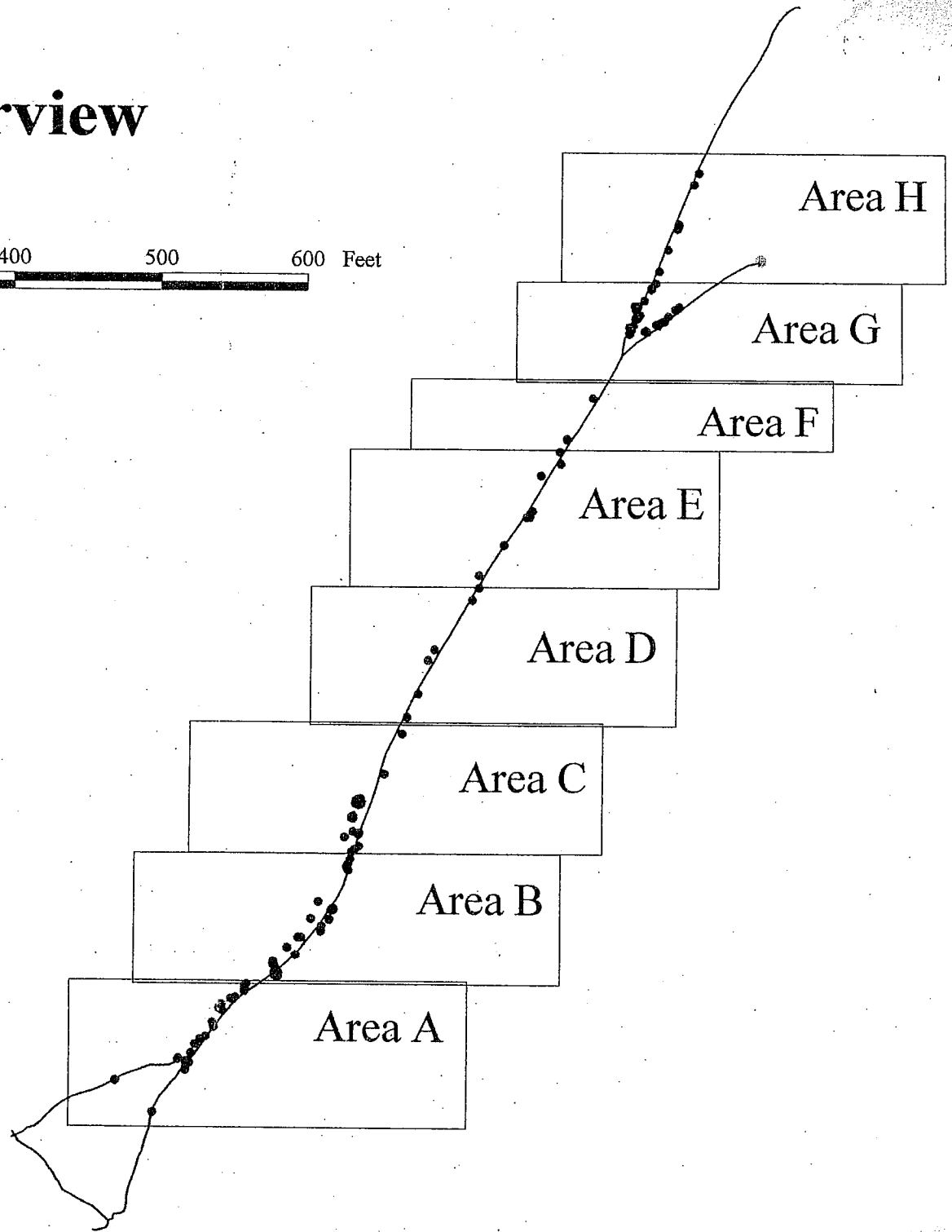
Gray Whale - Area C



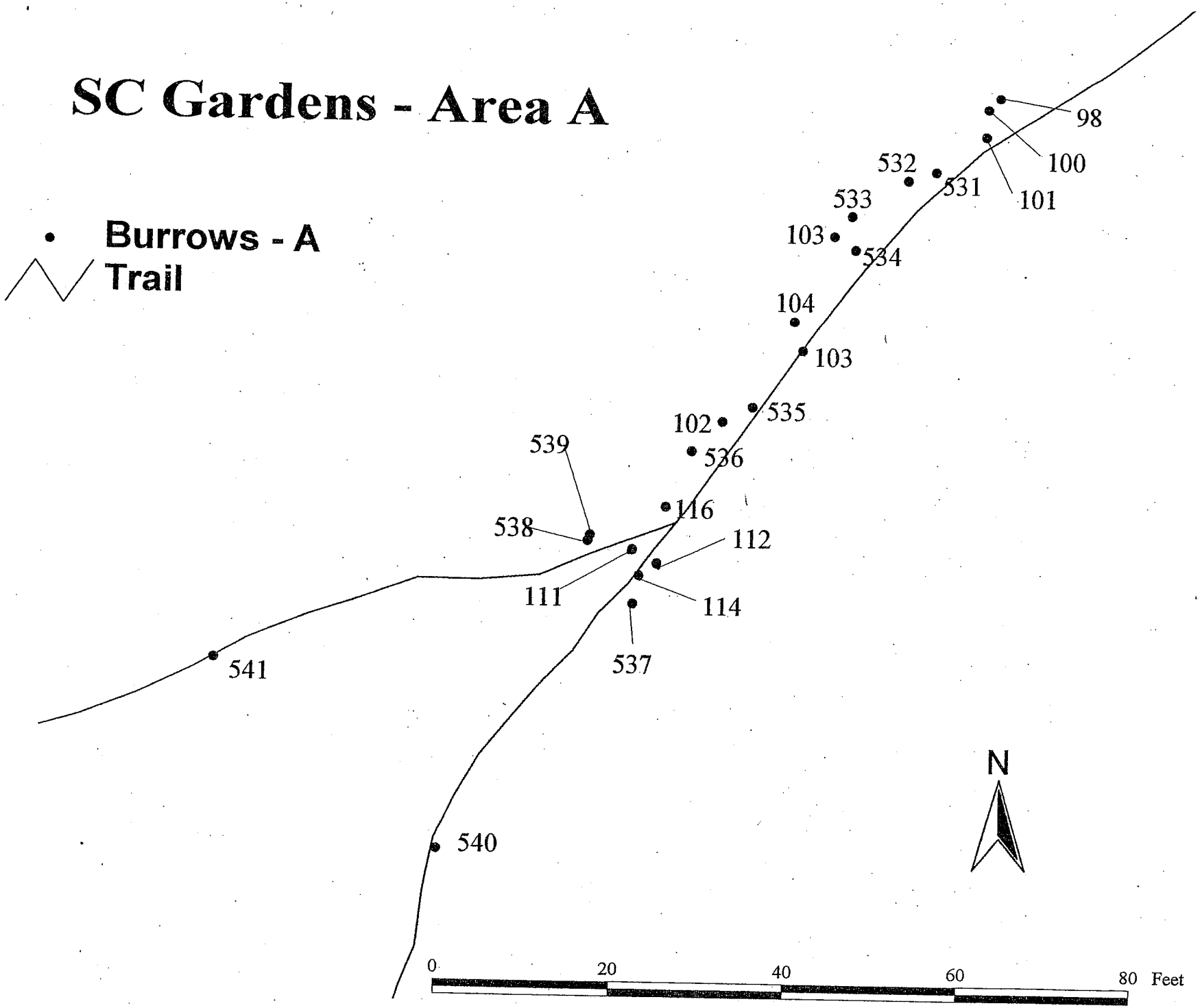
SC Gardens - Overview



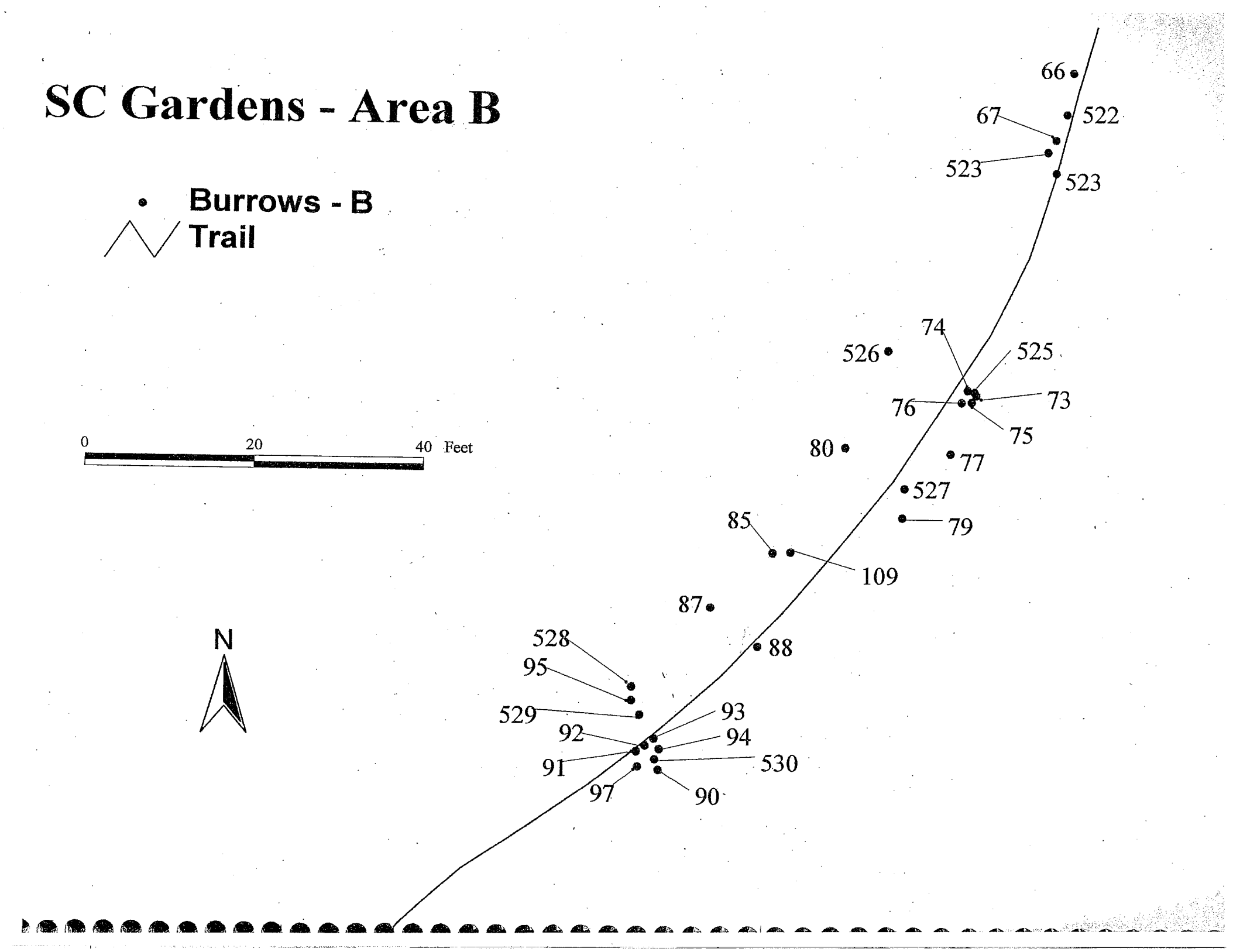
All Burrows
Trails
Post
Coyote Bush



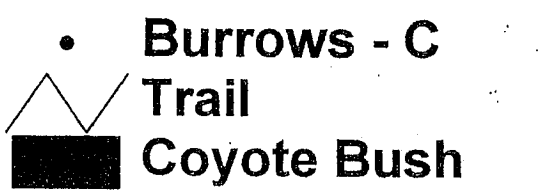
SC Gardens - Area A

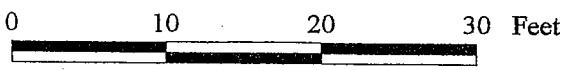


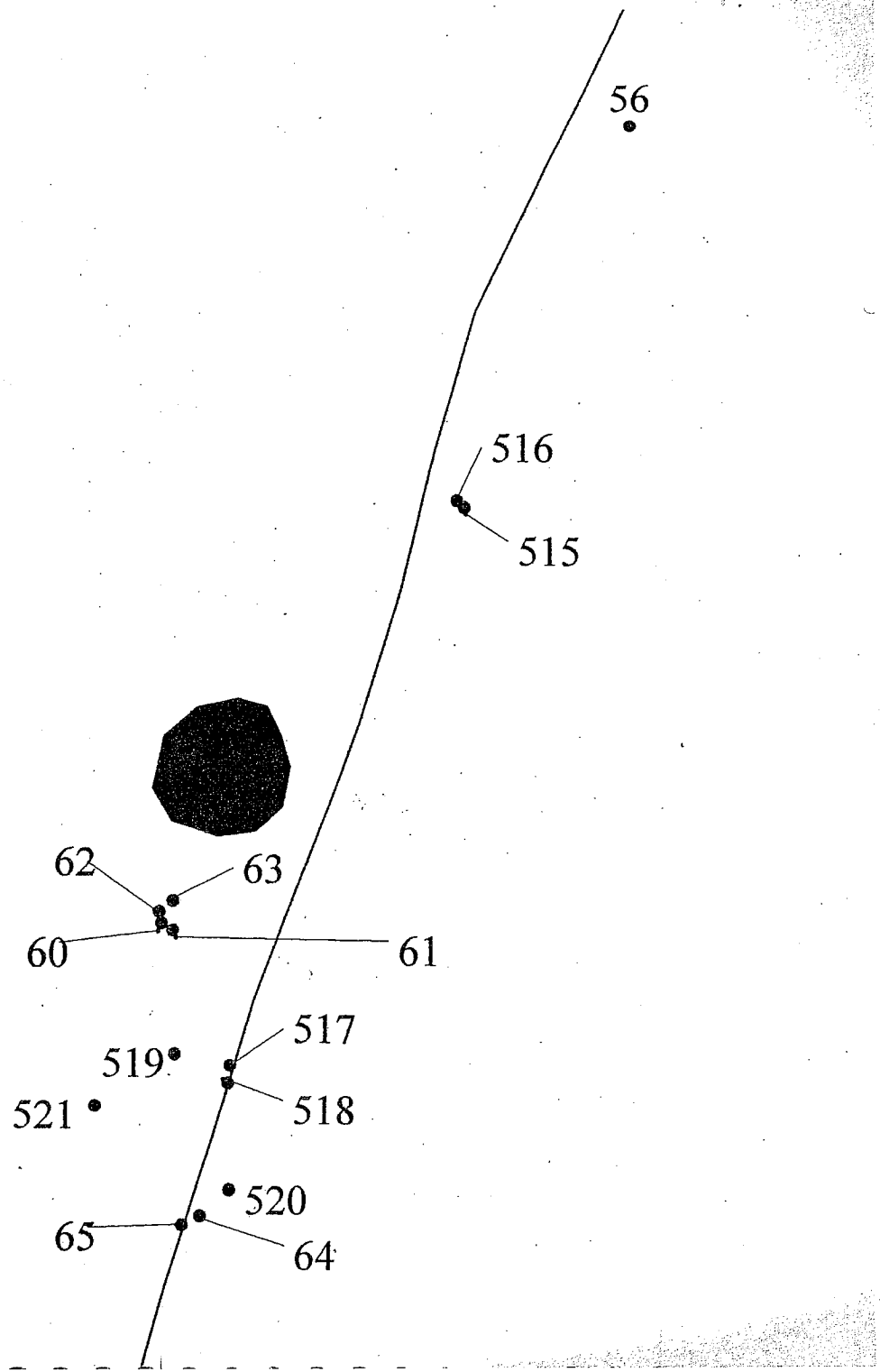
SC Gardens - Area B



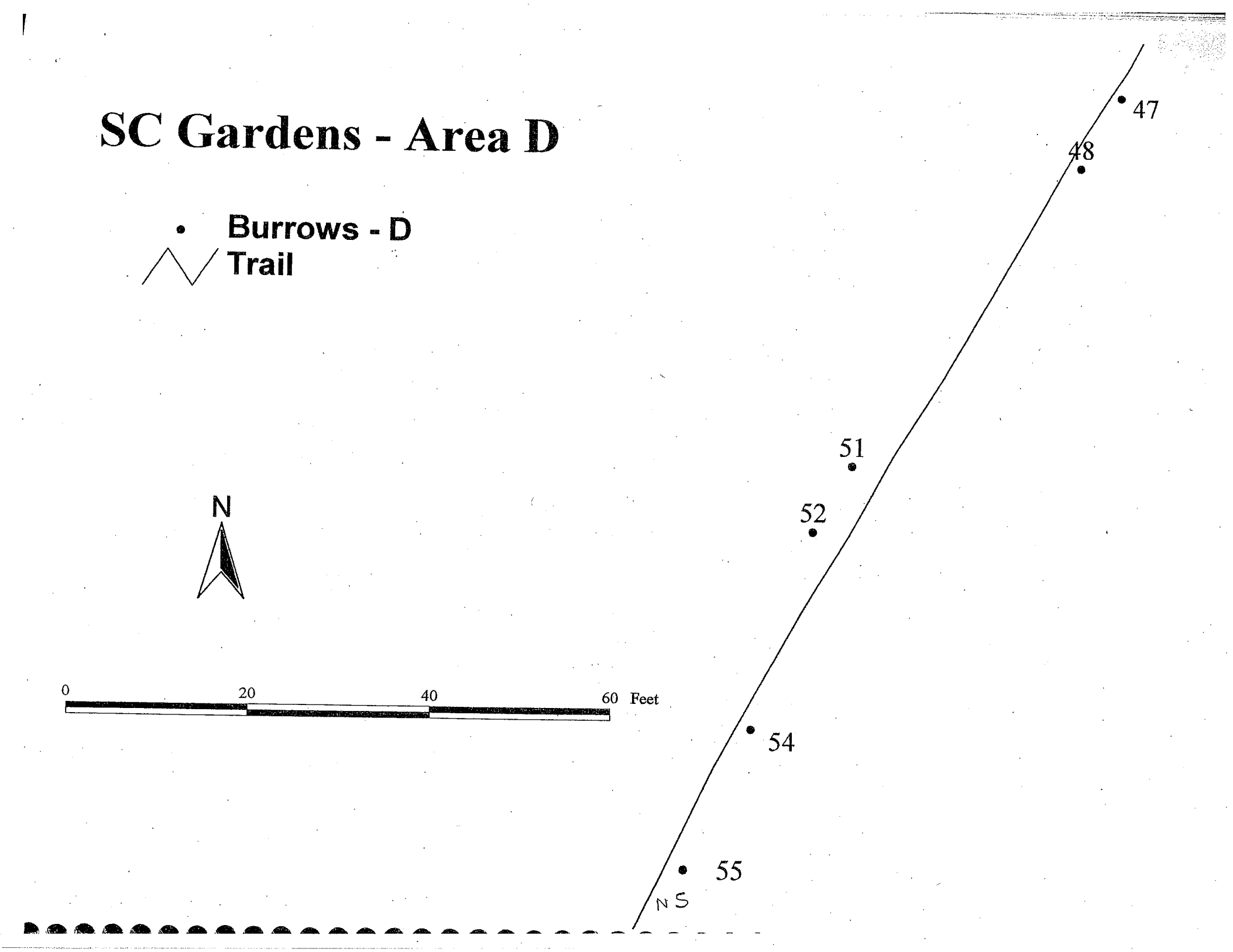
SC Gardens - Area C



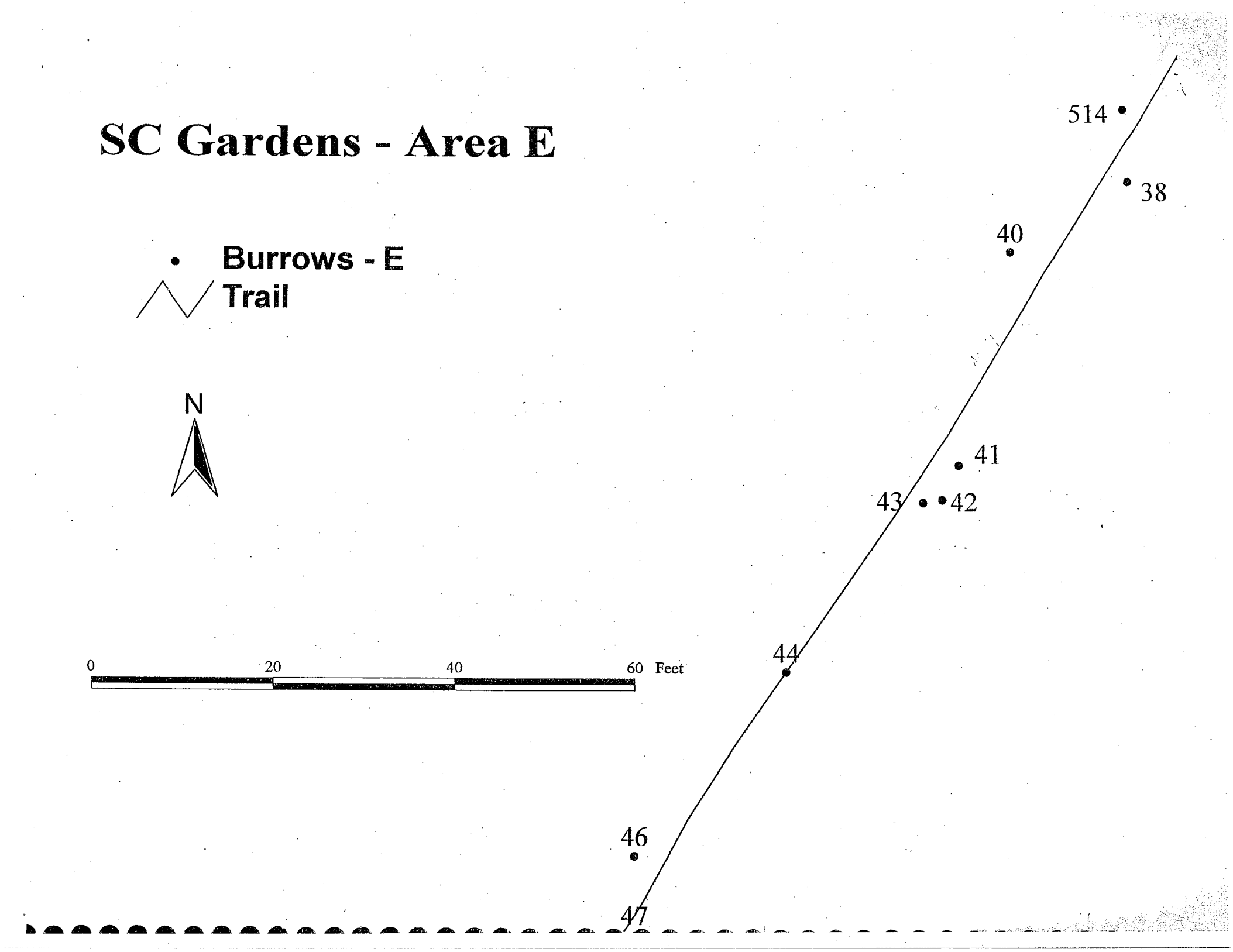




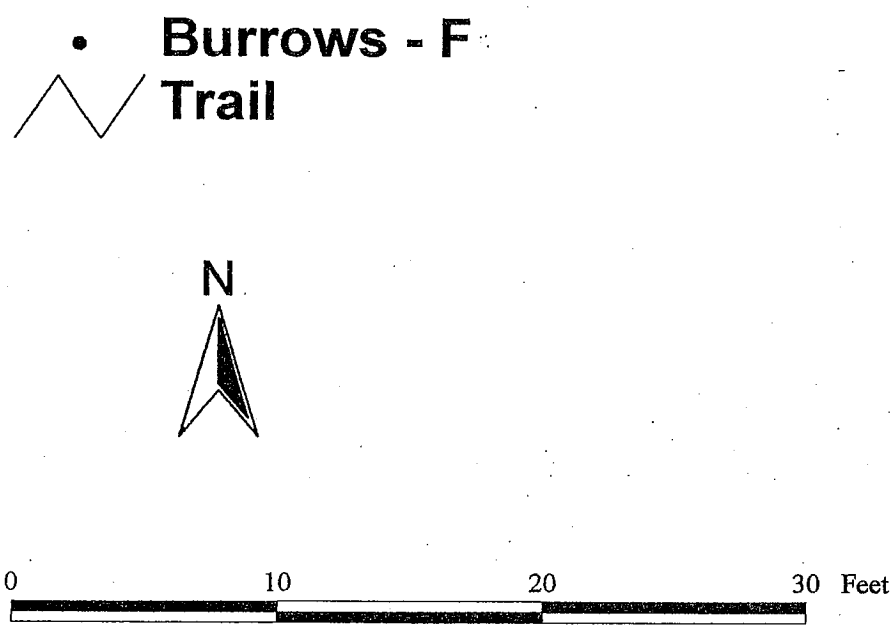
SC Gardens - Area D



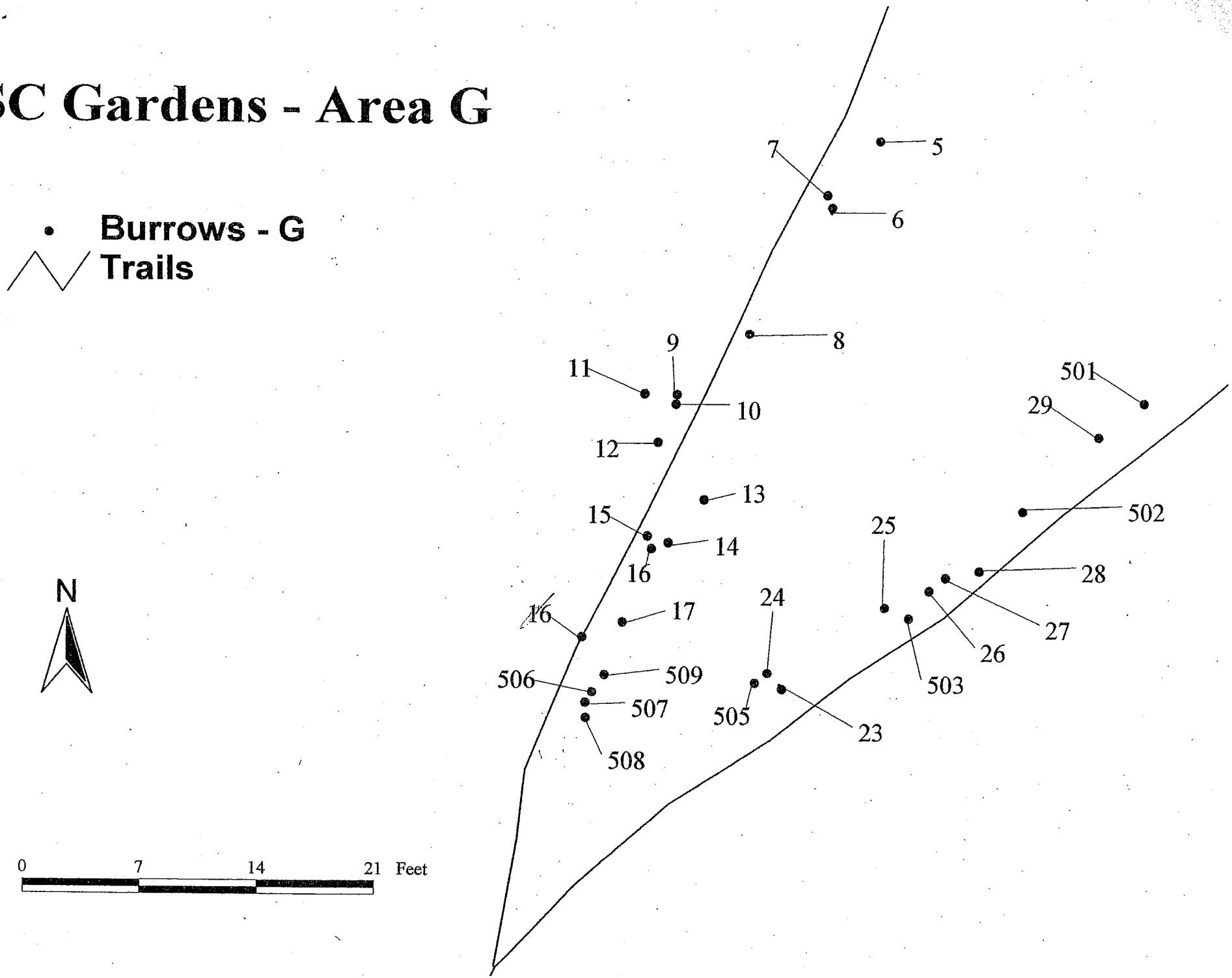
SC Gardens - Area E



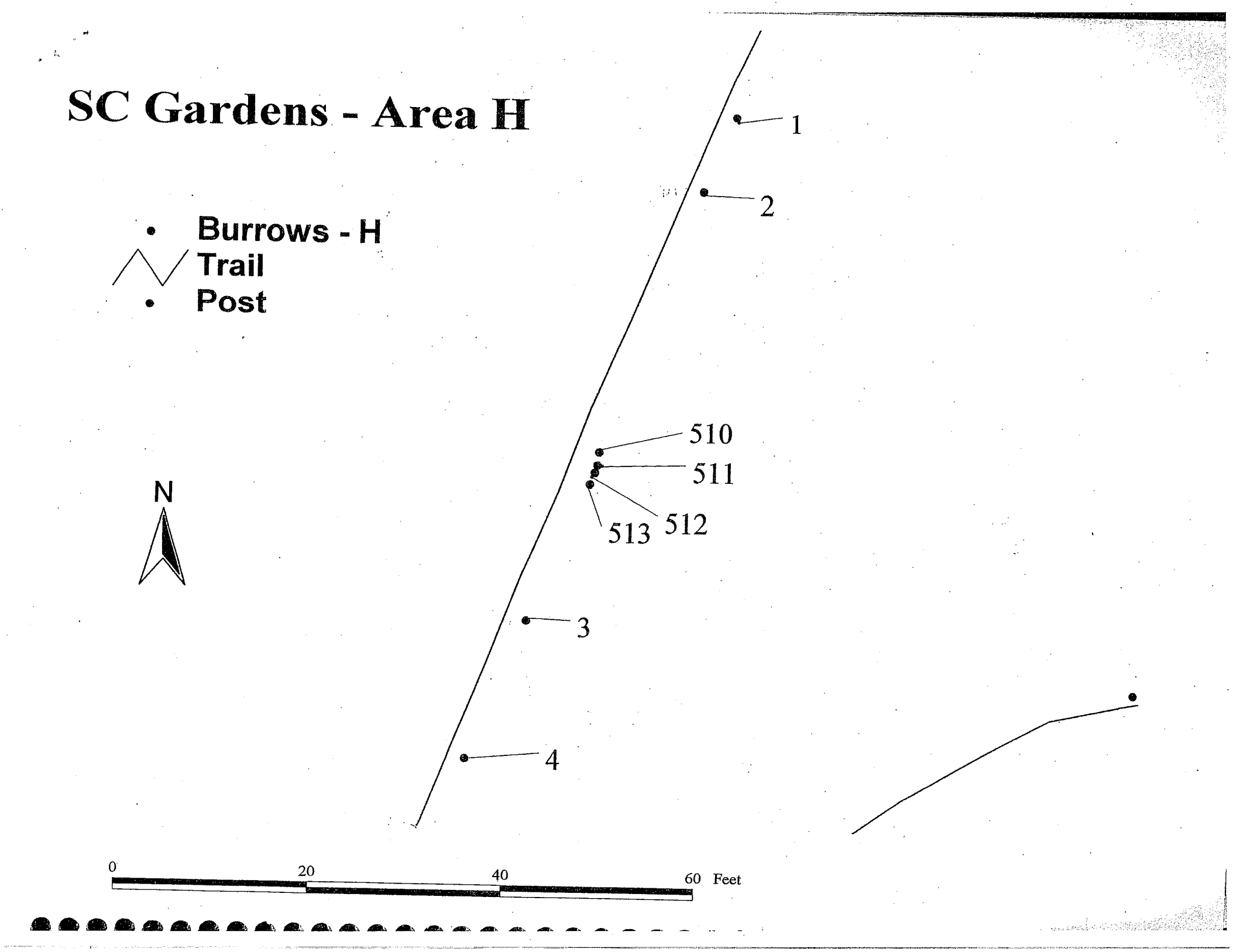
SC Gardens - Area F



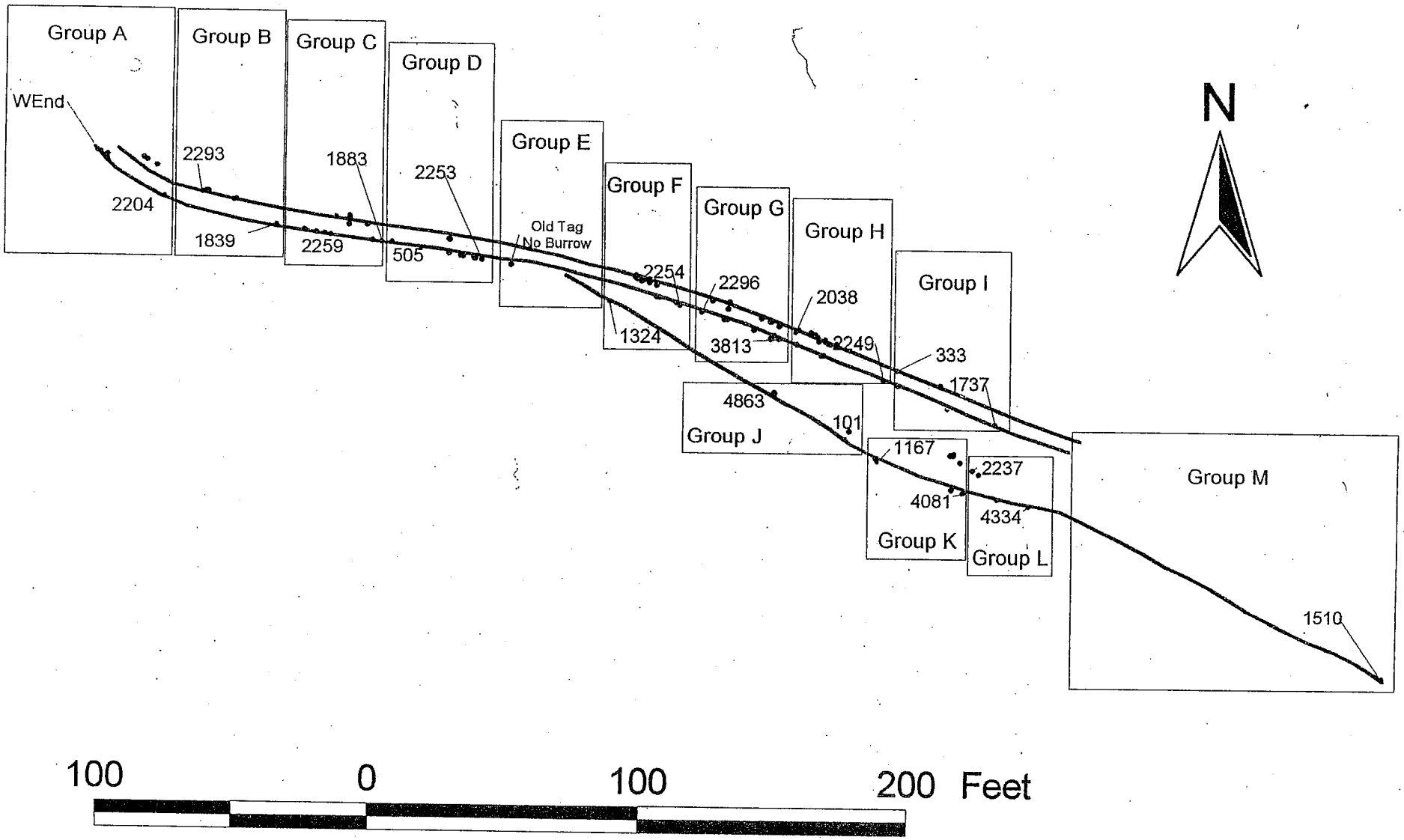
SC Gardens - Area G



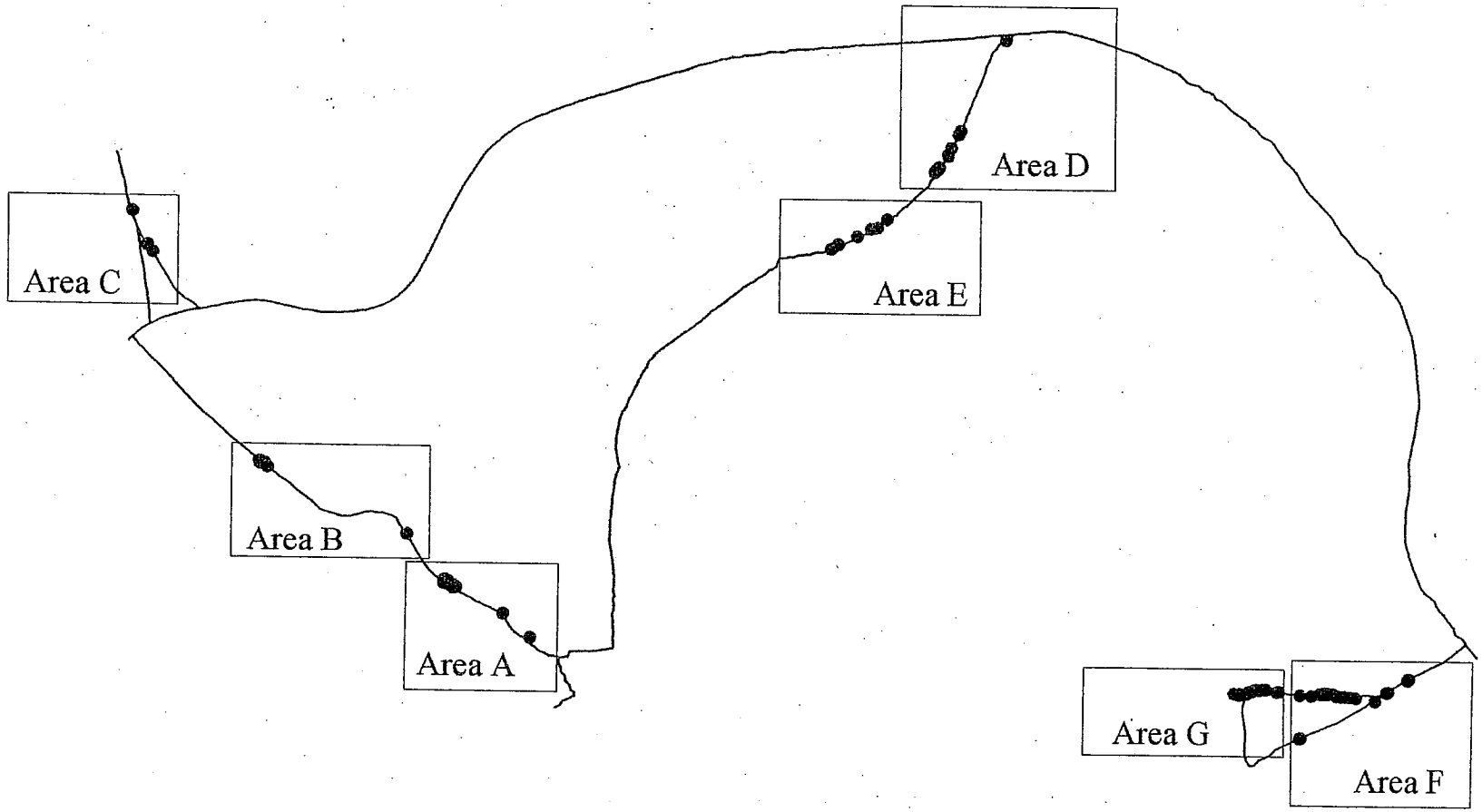
SC Gardens - Area H



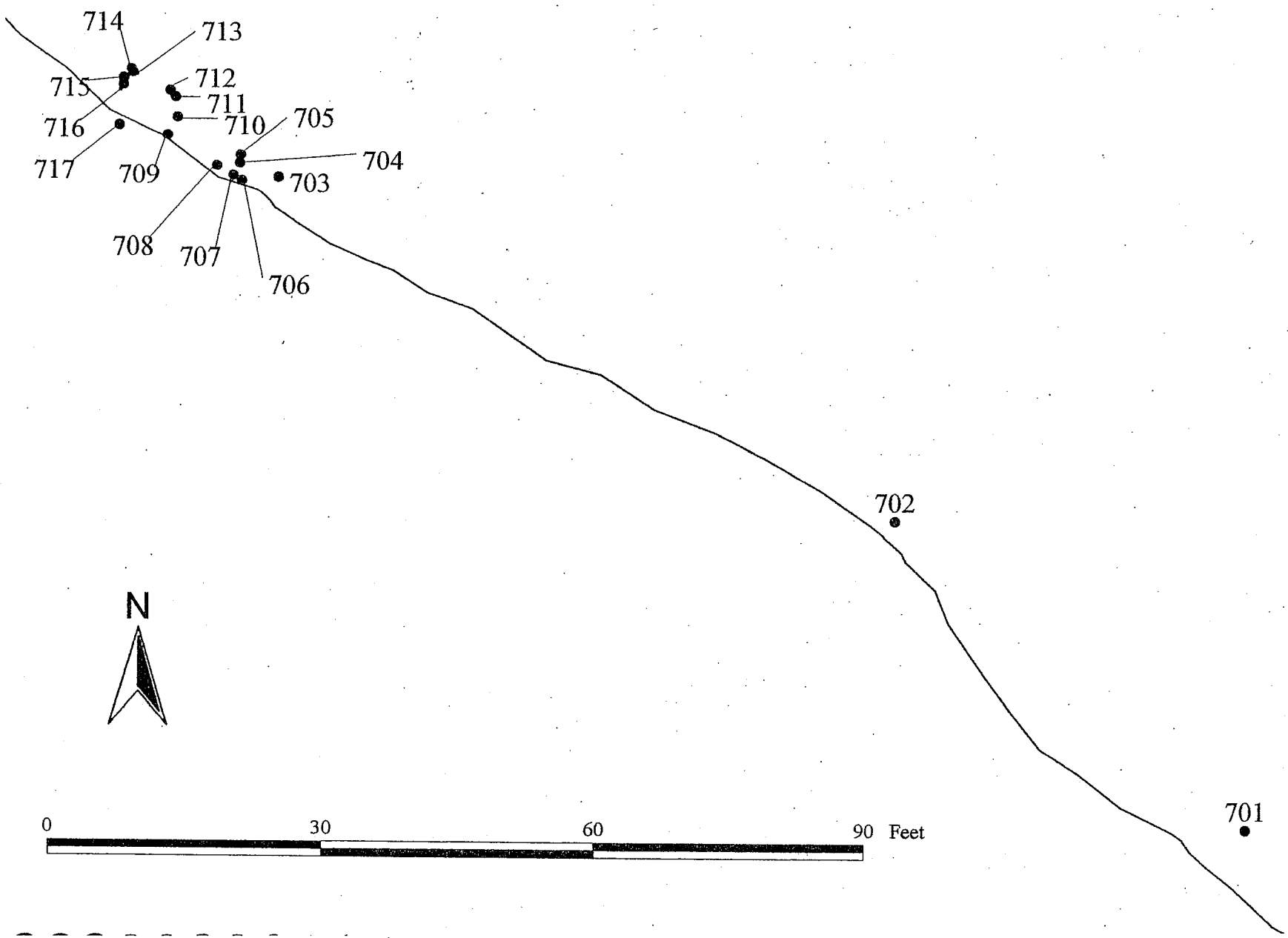
Ohlone Tiger Beetle - Poliski-Gross Site
Key to Groups on Detailed Maps



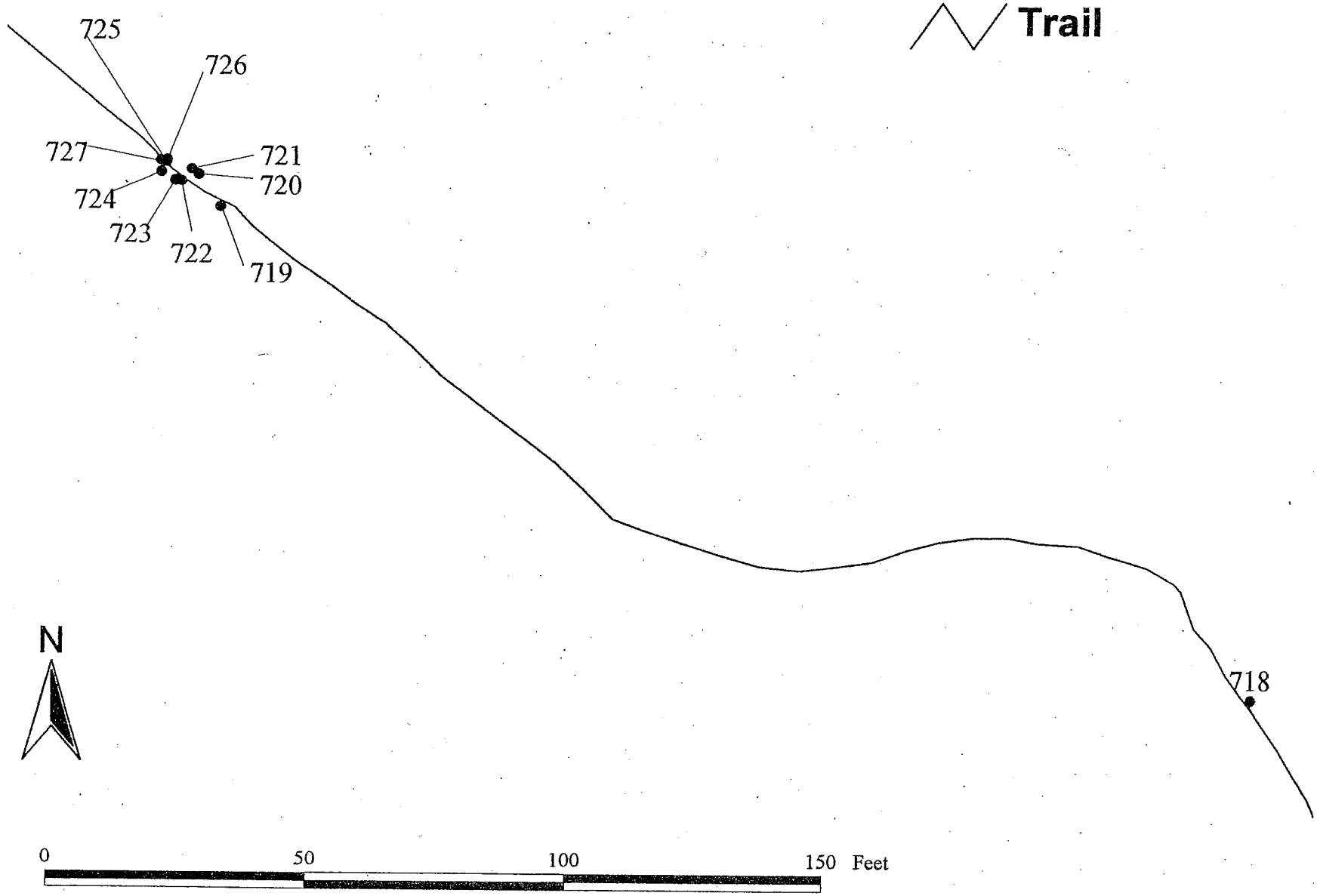
Marshall Fields - Overview



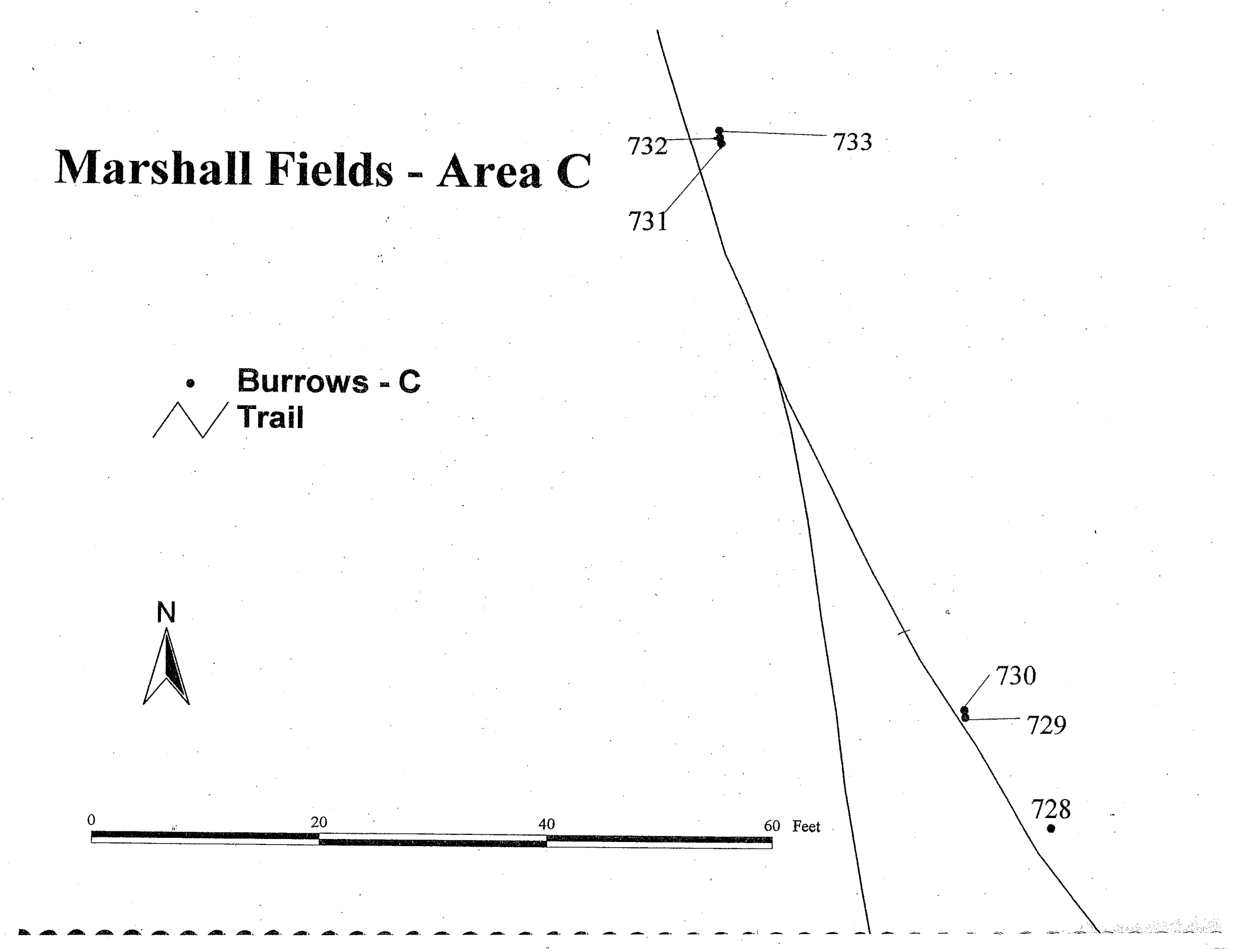
Marshall Fields - Area A



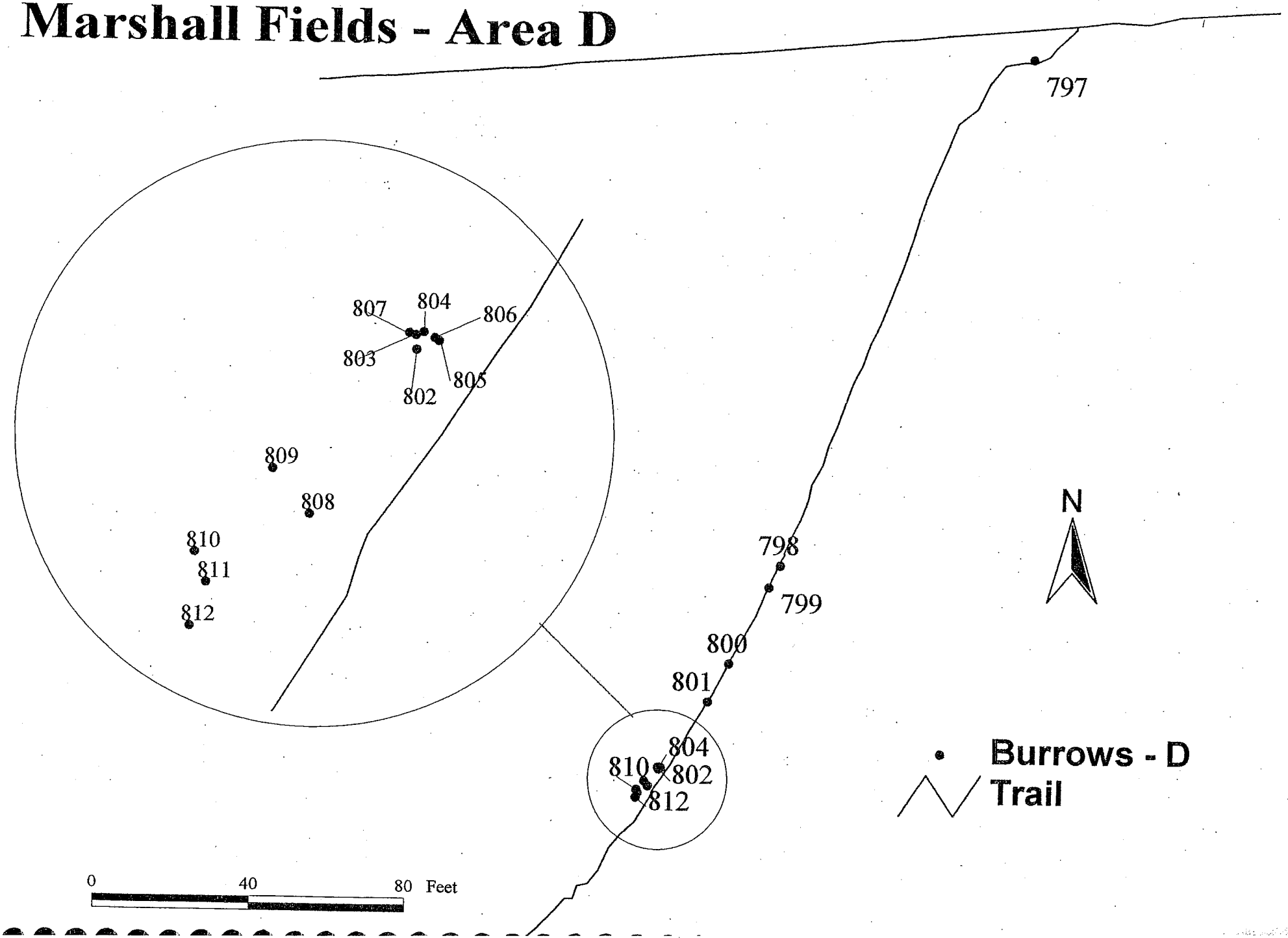
Marshall Fields - Area B



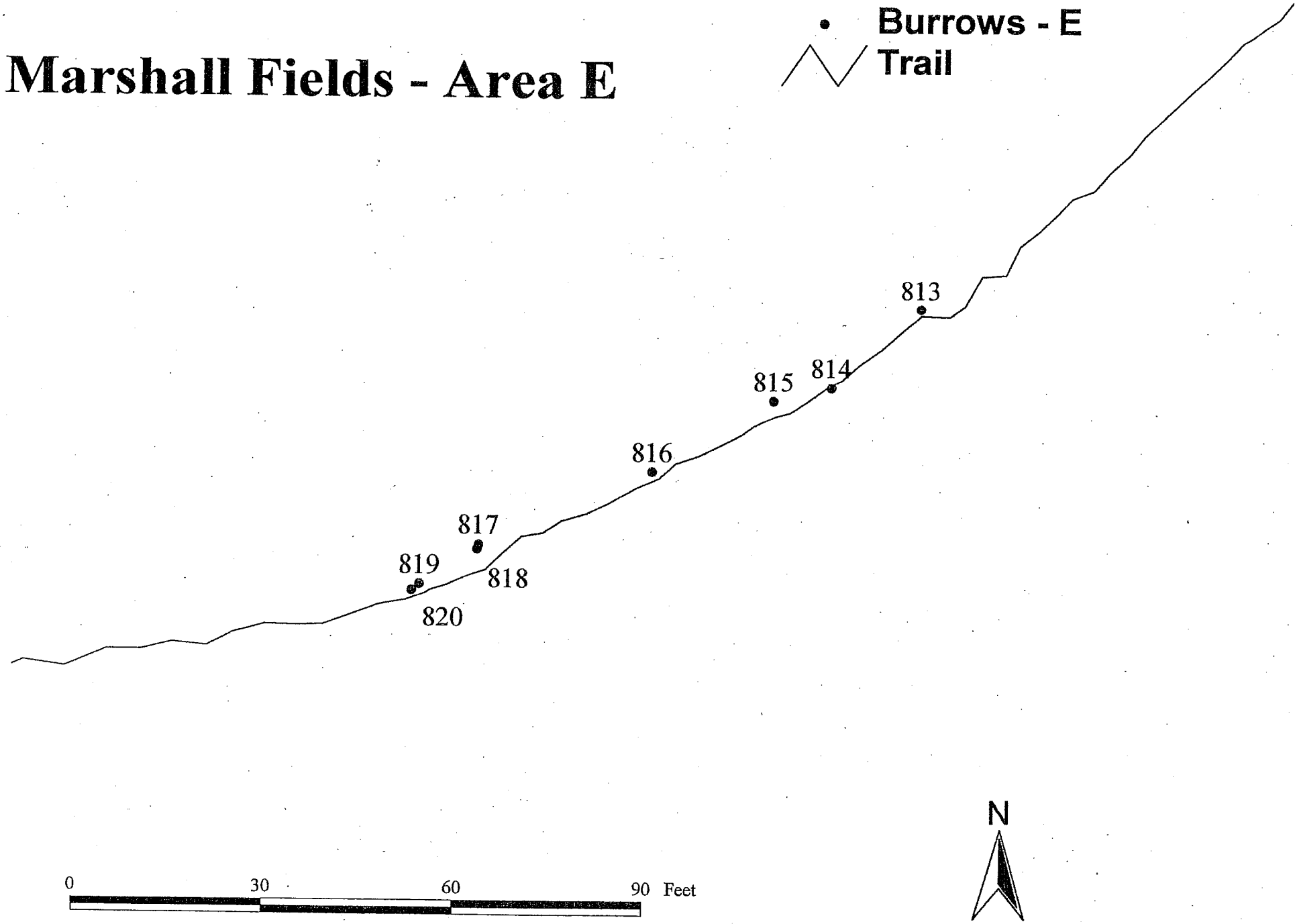
Marshall Fields - Area C



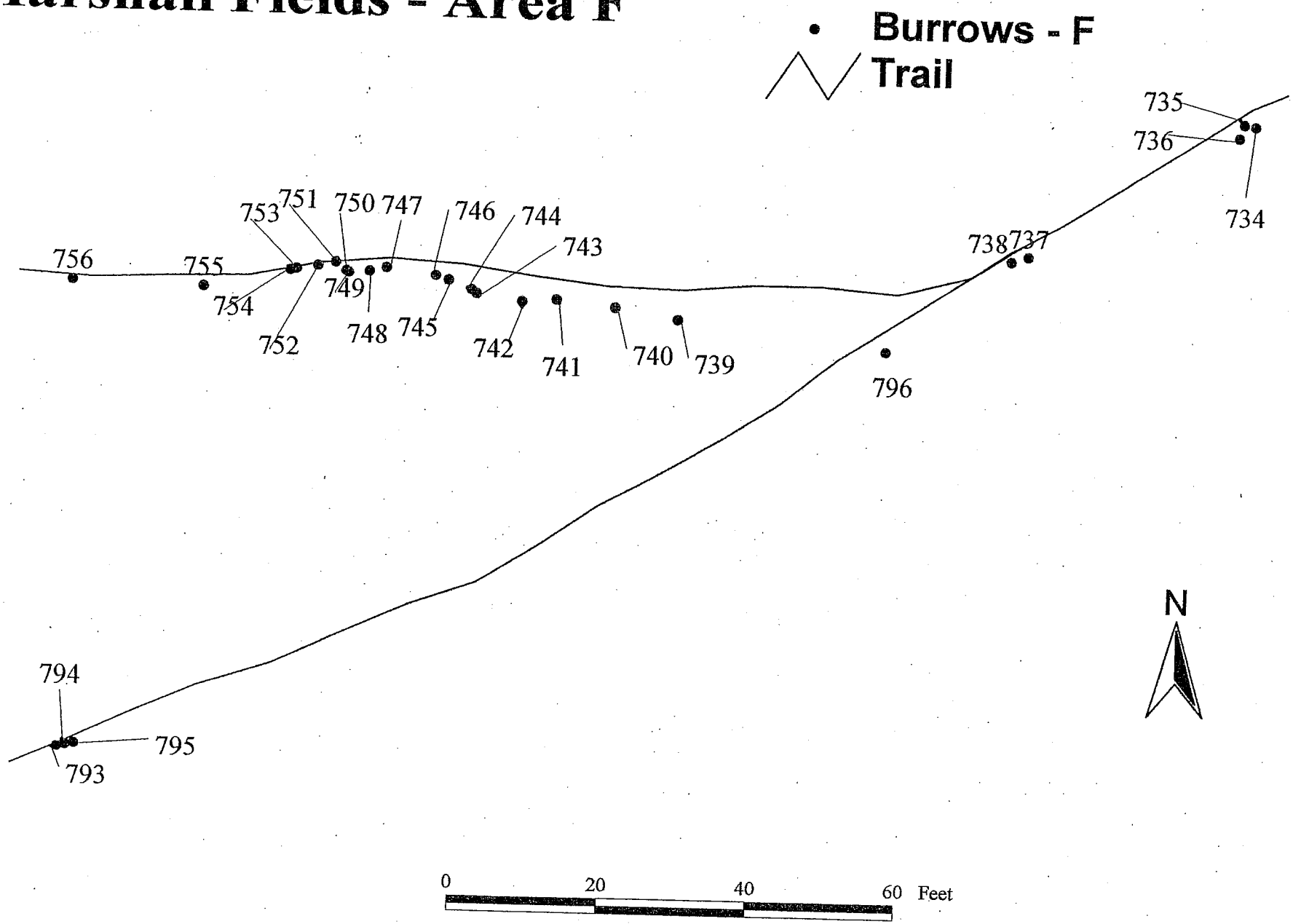
Marshall Fields - Area D



Marshall Fields - Area E



Marshall Fields - Area F



Marshall Fields - Area G