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Title: Evaluation of Compatabilities Between the Test Program and a Potential Waste Repositories, or Other Users, at NTS

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Very truly yours,

Barbara Killian

Barbara Killian

Encl: Evaluation of Compatibilities
Between the Test Program & a Potential
Waste Repository, or Other Users, at
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Evaluation of Compatibilities Between the Test Program and a Potential Waste Repository, or Other Users, at NTS

by

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PURPOSE AND SCOPE

This interlaboratory report is a reply to General Bratton's request of August 1977 which asked that the laboratories make an "evaluation of compatibilities between the test program and potential NTS waste repository sites." In the text, test program's current and projected uses of the various testing areas at NTS are delineated. Two additional technical criteria are then examined which would influence joint use of NTS: ground motion; and facilities, security, and safety aspects. Some nonquantifiable or administrative issues are also identified in the text which influence an evaluation of compatibility.

This report is intended to aid those tasked with making the important decisions regarding the future of the NTS, a unique national resource.

TEST PROGRAM'S VIEW OF THE NTS

The NTS is the only area where the U.S. will be able to regularly conduct underground nuclear weapons tests. The test program also recognizes the national importance of obtaining a usable geologic storage facility and the desirability to both test program and waste management of locating such a facility within or near the NTS.

We restate here some points made in our paper of September 1977.[1] "Current test programs are being conducted with the philosophy of conserving a finite and irreplaceable resource." "We think that the nuclear testing community should take a long-range view toward future capabilities, perhaps as much as 100 years."

We feel that it is of national importance to preserve capabilities at the NTS for testing, even during a period when nuclear testing might be prohibited. Without it, the U.S. might not be able to resume testing if other nations abrogate, evade, or withdraw from a test ban treaty; and a major deterrent to their doing so, could be lost.

TECHNICAL FINDINGS OF THIS STUDY

In Section I of this report, test program's current and projected uses of the various testing areas at NTS are delineated. A waste repository site would not be compatible with testing activities if it were located within any of the active testing areas: Yucca Flat, Pahute Mesa, Rainier Mesa, and the soon to be developed Buckboard Area.

There are three currently inactive test areas: Frenchman Flat, Climax Stock, and Shoshone Mesa, in which nuclear weapons tests were conducted in the past. Use of these areas by a permanent resident user, such as a waste repository site, would decrease the future flexibility of the test program. The test program must retain its current flexibility, including backups to currently active testing areas. Section I also describes the current status and the lesser projected needs of the potential test areas: Gold Meadows, Dome Mountain, Mid Valley, and Eleana Area, as well as the nonweapons testing area of Jackass Flats.

In Section II, three additional criteria are examined which influence the compatibility of joint use of the NTS: ground motion; facilities, security, and safety; and administrative issues.

In the ground motion subsection, we provide "state-of-the-art" site-general estimates of accelerations which could be expected from testing in the active areas and at Frenchman Flat, at probable yields. In this subsection, attention is called to an isolated case of anomalously large ground motions in order to alert a user to the need for site specific ground motion studies. As discussed in the text, there are a number of technical reasons why the estimates for these probabilities are expected to improve as data are gathered which enable the estimates to become site-specific. The test program is willing to cooperate with waste management in providing data and technical expertise wherever needed.

Technical problems such as ground motion appear to be solvable with adequate geographical separation from testing areas and with adequate design of a disposal facility. Compatibility with respect to ground motion as well as security and safety aspects appears to be greatest for a resident facility in the southwest portion of the NTS. Compatibility generally lessens as the resident facility moves closer to the testing areas. Compatibility is thought to be achievable with respect to use of existing facilities at NTS if a management policy of: (1) noninterference with test program, and (2) fiscal self-sufficiency, is carefully implemented.

NONTECHNICAL ISSUES

The main compatibility problems we have identified are administrative issues of a nontechnical nature. These issues center around the possible change in the currently favorable roles or attitudes that various bodies or groups have had with respect to weapons testing at the NTS when waste management cohabits the NTS. The main issues we identify are:

1) The possible future roles of regulatory bodies at NTS, such as NRC.
2) The future role of the state of Nevada and other public bodies at or around NTS, for instance, increased controls on transportation.
3) A change in the current public acceptance of nuclear weapons testing at NTS which could be induced by the opponents of nuclear waste storage who actively oppose <u>anything</u> nuclear.

RECOMMENDATIONS

We recommend that:

I. Areas of the NTS identified as Active Testing Areas and as Currently Inactive Test Areas be preserved solely for nuclear weapons testing activities.

II. Any permanent or demonstration waste storage facilities be located only in areas where: (1) personnel having access to the facility will not view testing activities and areas, either at the facility or in transit to it; (2) the storage facility can be geographically and physically separated from the weapons testing parts of the NTS, by fencing and separate access roads, to achieve both actual and "psychological" separation; and (3) the test program's capability to execute nuclear tests at all potentially acceptable yields anywhere within the Active and Currently Inactive Test Areas is not compromised.

III. DoE take the necessary steps to assure that NRC licensing of nuclear waste storage does not include any authority over the nuclear weapons test program.

IV. An administrative and management framework be established in the near future which assures that public relations activities of joint relevancy to test and waste will be carefully coordinated with test program. This coordination should be aimed at precluding any public antagonism against either waste storage activities or nuclear testing from impinging unfavorably or unnecessarily against the other program.

INTRODUCTION

The Nevada Test Site was developed and has been utilized as the U.S. nuclear weapons test site since 1950. Except for brief activities at other sites, the NTS is the only area where the U.S. has regularly conducted underground nuclear weapons tests.

With increasing frequency, proposals are being made to bring prospective new activities and users to the NTS. Among the recent proposals have been: the Navy's Seafarer-Sanguine, Air Force radar facilities for control of activities on the Nellis range, liquefied natural gas explosion studies, and studies on the preservation of desert ecology. Last August, the ANS was presented with a proposed program for the geologic storage of nuclear waste at the NTS. The national importance of geologic storage of nuclear waste is well recognized by the laboratories. Also, in the event of a test ban treaty, a waste repository at, or near, the NTS could aid in maintaining a viable work force at the NTS in a manner that a Readiness program alone could not.

Both the test program and waste management recognized the importance of assessing the impact of both programs coexisting at the NTS. To this end, last August General Bratton requested that the laboratories "examine your present and future requirements for testing in the various areas and geologic media at the NTS and provide me with your comments regarding Timber Mountain." Our response to this request was submitted in, "Test Program Needs for Timber Mountain/Buckboard Area," 14 September 1977, by LASL, LLL, DNA, SLA, and NVO.[1] Our response was largely based on an earlier study, "Final Report, NTS Real Estate Availability Study Group," 1 September 1977, compiled by the Nevada Operations Office.[2] Our recognition that the NTS is an irreplaceable and finite resource stimulated the real estate study.

General Bratton's August 1977 request also asked that the laboratories make an "evaluation of compatibilities between the test program and potential NTS waste respository sites" by mid FY78. This paper is an answer to that request.

In this report we:

1) Delineate the test program's current and projected uses of various testing areas at the NTS.

2) Identify and discuss factors which will influence the evaluation of compatibilities between the test program and potential users of the NTS, particularly the siting of nuclear waste repositories. One of the main technical factors in evaluating the compatibility of a permanent structure, such as a waste repository, is the ground motion from the nuclear weapons program which such a structure would witness. Therefore, current estimates of ground motions are included in this paper.

As mentioned above, a variety of potential users have recently expressed interest in utilizing the NTS. We have therefore tried to write this paper so that it could also apply to potential users other than waste management. We visualize the possibility of two types of users, resident and transient. By resident user, we mean: a user to whom a long-term commitment for using the NTS would be made; they would occupy a specific area(s) of the NTS for a significant period of time, years or more; they would construct "permanent" facilities and/or utilize NTS resources; and their presence could have a potential effect on the nuclear weapons test program. By a transient user, we mean: a user to whom no long-term commitment for using the NTS would need to be made; they may or may not actually occupy a specific area(s) of the NTS for any period; they would not construct "permanent" facilities; and their presence would not have a potential for significant effect on the nuclear test program. We view a waste repository at the NTS as being a resident user. In addition to ground motion, compatibility of users with respect to facilities, security and safety, and administrative issues are also briefly examined.

This paper is intended to aid those tasked with making key decisions regarding our unique resource, the NTS, in the best interests of national need.

SECTION I: AREAS SUITABLE FOR WEAPONS TESTING

Figure 1 shows the various areas of the Nevada Test Site. In their report,[3] the Data Exchange Working Group designated all of these areas except Jackass Flats as nuclear weapons test areas. The Jackass Flats area was excluded as a nuclear weapons test area in order that it might be used as an area for nonweapons testing, such as PNEs.

Table I summarizes the real estate assets in the areas shown in Fig. 1. These assets are stated in terms of the number of sites for individual weapons tests that these areas represent for the test program. The column labeled potentially acceptable yield gives maximum yield which the Ground Motion and Seismic Evaluation Sub-Committee to the NTS Planning Board (GM & SES) has designated as producing potentially acceptable ground motions at: Las Vegas, Indian Springs, Pahrump, Mercury, Beatty, CP-1, and the E-MAD facility. The GM & SES has determined potentially acceptable yield for only the areas of: Yucca Flat, Pahute Mesa, Frenchman Flat, and Buckboard Area. The values given in parentheses for the other areas in Table 1 are "best estimates" provided by the authors. The maximum probable yield stated in Table I is smaller than the potentially acceptable yield because of the test program's self-imposed conservatism with respect to ground motions at their on-site facilities at CP-1 and Mercury. The next three columns give the number of available sites for various yields in each area. This information was obtained from the final report of the Real Estate Availability Study Group.[2] The last column of Table I summarizes the current status and test program's projected needs for the various areas.

In the remainder of this section, the current status and the rationale for test program's projected needs are discussed for the areas listed in Table I.

ACTIVE TESTING AREAS

Nuclear tests are currently being carried out in the Yucca Flat, Pahute Mesa, and Rainier Mesa areas of the NTS. Each of these areas has unique geologic and geographic features which are very important to the current and future conduct of nuclear weapons testing. In each area, large investments have been made to develop roads, tunnels, support facilities, power distribution lines, water supplies, etc.

Because of the obvious need to relocate intermediate yield tests elsewhere than at Yucca Flat,[1,2] we have determined that the Buckboard Area must be developed as an active testing area very soon. Plans are now being made to increase our understanding of the geology of the Buckboard Area and to initiate emplacement hole drilling there, as soon as our budget will permit the modest "opening costs" of this area.

There is no question that the location of a new, long-term resident of the NTS within or near any of these areas would have the potential for obviating nuclear testing in that area. This would create a very severe impact on nuclear weapons test programs.

CURRENTLY INACTIVE TEST AREAS

A permanent geologic nuclear waste disposal facility would be a resident of the NTS for many hundreds of thousands of years. By comparison, the last 30 years have witnessed dramatic variations in testing activities at NTS which have been imposed by the development and maintenance of our nuclear arsenal. It is impossible for test program with its rapidly changing, variable, and unpredictable needs to evaluate now whether or not test and waste will be compatible at certain locations in "as long" (or "as short" when viewed by waste) a period as 100 years. Since a permanent nuclear waste facility will permanently remove areas from future use from the unpredictable needs of weapons testing, we believe that test program must not limit its current options and flexibility. We think that test program must maintain its policy of retaining backup areas in the NTS for the currently active test areas.

The test areas described below have been used within the last 12 years for nuclear weapons tests. These areas could be returned to for weapons testing. They represent a significant asset to the test program which we think should be retained solely for weapons testing.

Frenchman Flat

The Frenchman Flat area was actively utilized by LLL, LASL, and DNA as a test area for low-yield tests between 1965 and 1971. The Real Estate Study indicated that Frenchman Flat contains 143 sites for yields above 144 kt plus 516 sites for lower yields, a substantial real estate asset. Frenchman Flat is an area which the test program could presently reactivate and readily utilize. It offers considerable operational flexibility and back-up for our present and future testing options. Yucca Flat is presently more accessible to our support camps and is more desirable in terms of having both low and intermediate yield options. However, Frenchman Flat could accommodate low-yield tests during a heavy testing schedule; and it also represents an area that is isolated from our most active test areas.

Climax Stock

The Climax Stock was the site of the Piledriver and Hardhat events in the early 1960's. These DNA-sponsored events were directed principally toward study of the response of underground structures to severe ground shocks. Subsequent structural effects experiments in the softer medium of the Rainier Mesa have led the DNA to the conclusion that a hard-rock site, specifically the Climax Stock, would be the best known location of such future tests. The use of the Climax Stock for this purpose is an important aspect of our future testing capabilities.

Shoshone Mesa

The Shoshone Mesa region within Area 16 is a test area proven by past low-yield DNA events such as Gumdrop, Marshmallow, etc. The existing tunnel complex contains an explored working point and some facilities that could be readily activated. The area is considered by DNA as a first backup for the Rainier Mesa tunnel complexes. It is an area which could provide relief for low-yield events if close scheduling of activities within Rainier Mesa should introduce operational problems.

POTENTIAL TEST AREAS

Gold Meadows Stock

The Gold Meadows granite stock is considered by DNA to be an alternate to the Climax Stock for structural effects experiments in hard rock. The Gold Meadows Stock has not been explored as extensively as the Climax, but the presence of water in holes drilled to date suggests the formation may be more fractured than the Climax Stock. The presence of a perched water table combined with fractures would make the Gold Meadows Stock less desirable for testing than the Climax.

Dome Mountain

Dome Mountain is an undeveloped test area which DNA considers to be a backup to the Rainier Mesa tunnel complex for events with yields larger than those which could be contained by the Rainier Mesa overburden. Because of the steep slope at the point of tunnel entry, depths of overburden capable of containing up to 60 kt could be achieved by relatively short tunnel lengths.

Mid Valley

This area appears to be attractive for testing from the standpoints of cost and proximity to support facilities. The USGS report on Mid Valley notes: "The area is poorly understood geologically and geophysically. There are no drill holes." The regional water table is unproven and may be quite varied, especially over the Eleana formation which underlies parts of the valley. For intermediate yields, near the present 150-kt threshold, the number of sites is quite small and may approach zero. Thus, for shots in the intermediate yield range, the Buckboard Area is much more attractive. Although Mid Valley contains numerous sites for low-yield tests, the need for such tests is conditional upon using up available sites in Yucca and Frenchman over a relatively long period of time, or upon having those areas denied the weapons test community. Any activation of the Mid Valley area would need to be preceded by exploratory drilling to adequately characterize the geology and to assess drilling problems.

Eleana

The Eleana Area is known to have shallow paleozoic rock, and the Table I entry of 468 sites between 0-144 kt may be more heavily weighted toward the lower yields. The USGS Real Estate Availability Study indicates that the total thickness of alluvium plus tuff in the Eleana Area may be uniform but less than 1000 ft thick except between Mine Mountain and Syncline Ridge and along the Northern Eleana Range Block. The structure of the Eleana Formation is complex, and it constitutes a medium beyond our underground testing experience.

Hole Ue-1L was drilled as an exploratory hole for the proposed Yacht experiment. Drilling of this hole proved to be exceedingly difficult and costly. It is unlikely that the formation would be used as a site for underground weapons tests. Inasmuch as the Eleana Formation was identified as a possible site for underground nuclear rock fracturing experiments related to the Plowshare program, its retention for that or other purposes depends on whether experiments requiring the formation can be forecast.

EXCLUDED BY DATA EXCHANGE WORKING GROUP

Jackass Flats

Jackass Flats has been excluded from the nuclear weapons testing area of the NTS by the Data Exchange Working Group.[3] It has been mentioned as an area to be set aside for PNE experiments. However, the SURF test and demonstration currently being constructed at Jackass Flats would limit PNE testing options. In view of the U.S.S.R.'s continued position of excluding PNEs from a CTBT on a permanent basis, the desirability of setting aside this and other areas in or near NTS for PNEs needs to be re-evaluated. Because of the less desirable aspects of Jackass Flats for weapons testing, the testing community foresees no compelling need for the area.

SECTION II: THREE ADDITIONAL COMPATIBILITY CRITERIA

In this section, three criteria in addition to test program needs are discussed which influence the compatibility of the use of the NTS by both the test program and other programs. The three criteria discussed below are: Ground Motion; Facilities, Security, and Safety; and Administrative Issues. The criteria are discussed as they would relate to any new program at the NTS but with emphasis on a potential waste repository.

GROUND MOTION

Introduction and Background

Ground motions resulting from testing activities could affect other programs utilizing the NTS. Our intent is to provide estimates of ground motions expected from projected testing events at a realistic range of yields. The estimates are recognized as inexact, and we will mention what is being done to improve accuracy. Potential users of the NTS can utilize these estimates to assess whether or not ground motions from the various testing areas might adversely affect their activities.

The current emphasis on joint use of the NTS focuses on a terminal waste storage facility. There are three, yet to be determined, decisions associated with ground motion, which could affect the compatibility of such a facility with nuclear weapons testing at the NTS. These are:

1. NRC has not yet established ground motion criteria (either motion amplitudes or design response spectra) from either natural earthquakes or nuclear testing for which a waste facility must be designed in order to be licensed.
2. NRC has not addressed the question of what standard deviation in predicted ground motion will be acceptable.
3. The acceptable cost of hardening a terminal waste storage facility against nuclear explosion ground motion, when it is expected to exceed earthquake motion, has not been determined.

This report does not address hardening costs (Item 3). However, depending on decisions 1 and 2, Item 3 could be a key factor. A facility located at NTS will also experience recurring submaximum ground motion from various yield events. Recurring motion has not been considered.

Because decisions have not been made regarding Items 1 and 2 above, we consider the following:

1. NRC has established normalized design response spectra for the design of nuclear power plants (Regulatory Guide 1.60) to resist natural earthquake motions, and we assume their approach for a terminal waste storage facility will be similar. In this treatment we are providing only peak vector sums of acceleration, although separate vertical motion and horizontal vector motion, as well as frequency and response spectra, (Regulatory Guide 1.60) can readily be made available to a potential NTS user from the data bank. We have chosen to consider peak vector accelerations of 0.5, 0.7, and 1.0 g. No higher acceleration was contemplated because at peak values slightly above 1.0 g the edge of the spall zone is normally encountered. Inside the spall zone unique problems of facility design are encountered which it would appear better to avoid.
2. Regulatory Guide 1.60 does not deal with probability levels for earthquake motions at nuclear power sites, but does cite a reference[4] which treats probability levels of 50% (median), 84.1% (mean + one standard deviation), and 97.7% (mean + two standard deviations). Therefore plus one and two standard deviations have been used here for upper limits of nuclear explosion-induced ground motion.

<u>Approach to Estimating Ground Motion</u>

The approach used in this treatment is confined to estimating surface ground motion as a function of distance and yield. Attention is focused on peak vector acceleration although peak vector velocity and displacement can also be made available. We will:
1. Review an old method of predicting nuclear ground motion,

2. Describe why it appears to be inadequate for determining ground motion as it relates to compatibility at the NTS,
3. Describe what is being done to improve prediction capability,
4. Show the results of those efforts to date, and compare those results with the old prediction method.

We have limited our concern to four testing areas: Yucca Flat, Pahute Mesa, the Buckboard Area, and Frenchman Flat. Because of similar geology ground motion in the Buckboard Area, where no events have been fired, is assumed to be similar to that from a comparable yield in Pahute Mesa. Also motion due to tests in Frenchman Flat is assumed to be comparable to that from tests in Yucca Flat. For each of the areas considered, the following have been adopted in this section as maximum probable yields: Pahute Mesa - 1000 kt; Buckboard Area - 750 kt; Yucca Flat and Frenchman Flat - 250 kt. These limits are predicated on avoiding damage outside the NTS, as well as to test program facilities within the NTS. Not all of Yucca and Frenchman Flats are available for the maximum probable yield, but the entire areas are available for smaller yields. We have also considered the ground motion from 50 kt and 5 kt tests in Yucca and Frenchman Flats in the regions where such tests can be conducted.

Discussion of the four topics listed above follows.

1. Old Prediction Method - In 1970 the Environmental Research Corporation (ERC), using ground motion records from a number of events at NTS[5], developed prediction equations for acceleration of the form

$$a = KW^{n}R^{-m}$$

where W is the yield in kilotons, R the distance in km, and K, m, and n are empirical constants. Equations of this form were developed from regression analyses of measurements made over a distance range to as much as 400 km on a large number of events, with yields from less than a kiloton to over a megaton. From their equations, the two most applicable here are the one derived from events in tuff in Yucca Flat and the one for events in Pahute Mesa. From these equations the mean, +1σ and +2σ values of acceleration have been determined. The equation for Yucca Flat is:

$$a = 0.0903\ W^{0.588}\ R^{-1.37}\ (\sigma_a = 2.26,\ \sigma_R = 1.81) \quad . \quad \text{Eq.(1)}$$

The equation for events in Pahute Mesa is

$$a = 0.249\ W^{0.464}\ R^{-1.34}\ (\sigma_a = 2.30,\ \sigma_R = 1.86) \quad . \quad \text{Eq.(2)}$$

NOTE: To conform to ERC terminology σ_a as used here is a standard deviation ratio applied to the predicted acceleration and σ_R, to ground slant range. The ratio is defined as

$$\left(\frac{\text{mean + standard deviation}}{\text{mean}}\right) .$$

2. Inadequacy of ERC Equations - Below are listed certain reasons why the ERC equations may not be the best for determining on-site ground motion at NTS. The equations were developed to predict ground motion at the greater distances, e.g. Las Vegas, and not at near field locations.

a. The data set included data gathered over a number of years with instruments of different response characteristics and at a different numbers of stations.

b. It has long been observed that the attenuation of ground motion is rapid close to the source and decreases less rapidly with increasing distance. Measurements used by ERC were made to large distances and especially concentrated in the vicinity of Las Vegas where the large alluvial valley enhances ground motion. Preferred data for locations at NTS would be limited to data collected on site, especially near the motion range of interest. Restricting the data set in this manner would tend to increase the calculated attenuation rate with distance and reduce the standard deviation for the range of distances of interest here.

c. The ERC analysis used yields covering a range from less than 1 kt to over 1 Mt. For the purpose of determining ground motion as it affects compatibility, we are concerned with yields close to the maximum probable yields for each of the areas. One ERC treatment[6] did a regression analysis of both a total data sample and one for shots with yields $\geq$200 kt. There were 1207 data points in the total sample and 275 in the high-yield data set. Their results show σ_a to be 2.33 for the total data set and 1.93 (the average of 1.86 for gage stations on alluvium and 2.00 for gage stations on hard rock) for the $\geq$200 kt set. Thus, there is a reduction in σ_a when only the larger yields are considered, the σ_a for $\geq$200 kt being .83 times that of the total data set. For Eqs. (1) and (2) this would translate into values of σ_R of the $\geq$200 kt data set being 0.87 times that from the total data set; i.e.,

$$\log 0.87 = \left(\frac{\log 0.83}{1.34}\right) \quad .$$

The foregoing reservations concerning acceleration apply as well to predictions of velocity and displacement even though they are not addressed here.

3. Efforts to Improve Predictions - The ERC equations were developed for making ground motion predictions beyond the relatively near-field region of interest here. Therefore, re-examination of ground motion data from measurements on or near NTS has been undertaken. This re-examination has been restricted to data from events with yields reasonably close to the maximum probable yields for the testing areas being considered. Data from yields different from the three maximum probable yields being considered here are being cube-root scaled to the appropriate probable yield.

The ERC analysis[6] notes that while displacement data show adherence to cube-root scaling, velocity data depart from it and acceleration data depart even more. They attribute this to the fact that the higher frequency content of the acceleration pulses is attenuated more rapidly than the lower frequencies of velocity pulses, which are in turn attenuated more rapidly than those of displacement. Frequency content of waves increases as yield is decreased, and we are minimizing this shortcoming of scaling by choosing yields near the maximum probable yield to which the data are scaled. Also, some of the shortcomings attributed to frequency attenuation with distance are being decreased by restricting attention to on-site data.

4. Results to Date - Table II shows the results of the four shots analyzed to date for which data were readily available. The table lists the distances in kilometers for mean values and the plus 1σ and 2σ values for the three levels of acceleration shown. The table also shows the σ_a and σ_R values. Figures 2a-2c show the distance relationships scaled to each of the maximum probable yields together with the plus 1σ and 2σ values for the event with the greater coupling.

Results based on the ERC prediction equations have been added to Table II and are shown in Figures 2d-2f for comparison with Figures 2a-2c. As discussed earlier, values for σ_R from the ERC calculations derived from the total sample may exaggerate ground motion estimates. Those from the same equations but using reduced σ_R to account for limiting the sample to yields $\geq$200 kt may be more realistic for Pahute Mesa. A user may wish to multiply ERC values in Table II for 1σ_R by 0.87 and for 2σ_R by $(0.87)^2$ to obtain reduced distances. It was noted earlier that the ERC distance dependence was weighted toward small values of the exponent by the large number of measurements made at the greater distances in the Las Vegas vicinity. This is indicated by the fact that the two shots shown in Figures 2a and 2b have values of the range exponent, m, of 1.44 and 1.52 compared with an ERC value of 1.34 while those of Figure 2c have values of m of 1.80 and 2.03 versus an ERC value of 1.37.

Discussion and Interpretation

Table III shows the distance between the testing areas under consideration and what we understand may be potential candidate sites for a terminal waste storage facility. A comparison based on the distances of Table III and those of Table II shows the following based on ERC total sample values.

1. For testing at Yucca Flat there is a less than 2.3% probability that peak vector acceleration will exceed 0.5 g at Jackass Flat, Calico Hills, and Skull Mountain. Climax is at the north end of Yucca Flat where testing at up to 250 kt could extend as far north as N266,000 m, testing at up to 50 kt as far north

as N272,300 m, and testing at up to 5 kt as far north as N273,800 m. This means that the Piledriver shaft is about 9.4 km away from potential 250 kt tests in Yucca, 3.0 km from 50 kt testing, and 1.6 km from 5 kt testing. At the 2σ confidence level, 250 kt tests would cause maximum accelerations at Piledriver of slightly over 0.5 g, 50 kt tests would cause nearly 1.0 g accelerations, and 5 kt tests would cause about 0.6 g accelerations. The Eleana borders Yucca Flat on the west side and there would be about a 2.3% probability of exceeding 1 g from maximum potential yield events fired in the portion of Yucca Flat reserved for the large yields. Thus a facility at that location has the potential of interfering with the weapons testing program.

2. For testing in Pahute Mesa there is a less than 2.3% probability that the peak vector acceleration will exceed 0.5 g at Jackass Flat, Calico Hills or Skull Mountain. There is a less than 2.3% probability that it will exceed 1.0 g at Eleana and less than a 16.7% probability that it will exceed 1.0 g at Climax.

3. For testing in the Buckboard Area there is a less than 2.3% probability that peak vector acceleration will exceed 0.5 g at Jackass Flat or Skull Moutain and the same probability that it will exceed 0.7 g at Climax. There is a slightly larger probability that it will exceed 0.7g at Calico Hills. An event would have to be at least 12.1 km from the Eleana site before there would be a less than 2.3% probability that peak vector acceleration would exceed 1.0 g. The eastern boundary of the Buckboard Area is at about the E189,000 m coordinate, and about 5.6 km from the western boundary of the Eleana site. Thus there is the potential of interference with the weapons testing program in the eastern 6.5 km of the Buckboard area.

4. For testing in Frenchman Flat there is a less than 2.3% probability that the peak vector acceleration will exceed 0.5 g at any of the candidate sites listed.

Because of the depth to the carbonate paleozoic rocks, Frenchman and Yucca Flats present situations wherein the maximum probable yield can only be detonated within limited portions of these test areas. As the cover over the paleozoic rocks thins toward the edges of the test area, sites are available for smaller and smaller yields. The result is that a larger acceleration may be imposed on a site very near the edge of Yucca Flat (for example) by a smaller yield close by than would be imposed on the same site from a maximum probable yield where cover is adequate.

5. Another means of considering the foregoing results is illustrated in Figs. 3a-3d. These illustrations do include consideration of Rainier Mesa although not specifically discussed above. In Fig. 3a the active testing areas plus Frenchman Flat are color accented. Note that the southern edge of Pahute Mesa is omitted here because of rough topography. Note also that those portions of Frenchman Flat and Yucca Flat usable for $\geq$250 kt, $\geq$50 kt, and $\geq$5 kt tests are denoted. We then plotted the 1.0 g and 0.5 g contours around each of these areas or portions of areas using the appropriate ERC equations to calculate mean values, $+ 1\sigma$ values, and $+ 2\sigma$ values for range. Figure 3b is a composite of these contours using the mean calculated ranges to 1.0 g and 0.5 g. There is a 50% chance that the 1.0 g and 0.5 g levels will not extend outside these contours. Figure 3c shows the $+ 1\sigma$ ranges for 1.0 g and 0.5 g accelerations; it is 84% probable that those contours constitute upper limits of range. Finally, Fig. 3d shows the $+ 2\sigma$ (98% confidence) range contours.

These figures are not meant as highly accurate representations of expected ground shock environments created by nuclear testing at the NTS. They are rather an aid to making first approximations of the worst case ground motion at any location on or near the NTS as a result of future nuclear testing up to maximum probable yields. Specific analysis of particular proposed experiment sites should always be made to provide more accurate information for those locations.

6. An apparent seismic "hot-spot" which has been termed the NRDS anomaly has been measured in Jackass Flats on a limited number of events. On the Purse event the peak vector acceleration was at about the $+3\sigma$ level with respect to the mean value from the ERC prediction equations. That for Benham and Chateaugay were at about the $+2\sigma$ level. All three of these events were on a common azimuth (N 18 W) with respect to the point of measurement at Engine Test Stand 1. Although measurements were made on a number of other events (with different azimuths), an amplification of signals was not observed. Records from those three events where amplification was noted, are different in two respects. First, the dominant frequency in the spectrum is about four times higher than that of shots on other azimuths. Second, the peak amplitude occurs at the arrival of the first signal, whereas the signals from events on other azimuths have peak amplitudes occurring later in the wave train. It is emphasized that the maximum acceleration observed on the Purse event at Engine Stand Cell 1 was only 0.14 g and that other similar anomalies have not been observed on the NTS. The Terminal Waste Storage Program is currently sponsoring measurements designed to improve understanding of the mechanisms contributing to the anomaly.

Summmary of Ground Motion Subsection

The estimates provided here should indicate to a potential user of the NTS whether or not ground motion will be a first order problem. Figures 3b-3d indicate the close grouping with respect to distance of various g levels for a given error estimate (mean, + 1σ , or + 2σ). Significant differences do, however, occur as one goes from the mean to the 1σ and 2σ estimates. Thus, required design criteria which are dependent upon levels could be critical. As indicated in this subsection, the determination of accurate values for σ requires more site-specific work.

Technical problems such as ground motion appear to be solvable with adequate geographical separation from testing areas and with adequate design of a disposal facility. Compatibility between test program and a resident waste repository facility appears to be greatest for a resident facility in the southwest portion of the NTS. Compatibility generally lessens as the resident facility moves closer to the testing areas.

FACILITIES, SECURITY, AND SAFETY

Facilities for personnel and equipment at the NTS have in the past been well managed by NTSSO. Arrangements must be made so that the weapons test program is assured that facilities and manpower to meet its requirements are not siphoned off by new resident users. We have been assured by NTSSO that as personnel facilities and/or equipment would be needed by other programs, NTSSO would provide them with a policy of: (1) Noninterference with test program, and (2) Fiscal self-sufficiency. Hence, a new resident user must furnish resources for expanding facilities and manpower to meet its needs. New users should recognize that even now, on occasion, Mercury facilities and support manpower are saturated.

Test program's past arrangement with the Rover Project at Jackass Flats was similar to the above described NTSSO policy. Nevertheless, this arrangemment caused the test program intermittent anguish as well as dollars. We believe that a future arrangement between test program and another activity can be made to work effectively if it is well managed and if constant communication is open between the two activities. However, we emphasize that Rover was in Jackass Flats, not in the center of, or on adjacent borders of, ongoing testing activities.

Security (possible access of uncleared personnel to test program information) and safety (such as controlled areas during testing activities) will also influence compatibility. It is beyond the scope and expertise of this group to thoroughly evaluate national security and/or safety problems that might arise. However studies (of the type recently performed by NVO[7]) can be provided which treat compatibility criteria such as: constraints to test program operations; exposure to any fallout patterns resulting from an accidental release of radioactive material, and control procedures during testing activities. The NVO report summarizes by stating that sites located in the northern portion of the NTS have the highest potential for exposure to accidental fallout trajectories. The potential exposure decreases as the site location moves to the east or west and is lowest toward the south. Evacuation plans and potential exposure liabilities will require careful planning, but in many areas of the NTS these operational issues should present no serious obstacles to compatibility.

Before another resident user is allocated an area at NTS, the demarcation between that area and the weapons test areas must be clearly defined. Further, security measures to prevent other resident users from having access to weapons testing information must be established. For example one can see from the NTS area map in Fig. 1, the Jackass Flats area could be more easily isolated from nuclear weapons test activities than are some other areas such as the Eleana at Syncline Ridge and Climax Stock.

ADMINISTRATIVE ISSUES

A significant concern exists regarding the administration of both waste management and the test program at the NTS. This concern centers around the possible future roles of regulatory, state, and other public bodies at the NTS, as well as intervention by dissidents.

A high level waste isolation program will be required to seek licensing from NRC for a permanent, or even a nonpermanent, geologic storage site at NTS. A nuclear test results in weapon debris, the composition of which may reveal classified aspects of weapons design. DOE must assure that NRC licensing of nuclear waste storage does not include any authority over the established nuclear weapons test program.

Additionally, other regulatory bodies or public intervenors could possibly become much more vocal in their oppositions to testing or to waste storage if the two activities are "too close" together. Pressures imposed by intervenors could have adverse affects on both test program and waste storage activities which are greater than when these activities are viewed separately. For example, intervenors may view both the Climax Stock and the Eleana Area as being "too close" to testing activities. Either a demonstration or a permanent waste storage facility will generate a variety of visitors. In our opinion, such visitors should not pass through the testing areas of NTS or view testing activities. For example, an area such as Jackass Flats is geographically, as well as psychologically, somewhat removed from the areas of active or projected weapon testing activities. Such issues as these need to be carefully studied before a clear statement regarding compatibility can be made.

When the NTS was developed as a nuclear weapons test site in 1950, a great deal of personal contact was established with the nearby local residents and towns. Al Graves, Bill Ogle, and Jim Reeves, as well as others, spent years establishing local relationships and credibility.

The subsequent efforts by NV staff have also aided in preserving public acceptance in southern Nevada of the nuclear weapons testing program. We believe that the test program's successful and unhampered operations through the years can be attributed in great measure to the personal efforts of these individuals.

Recent NRC and DoE public hearings on the WIPP facility in New Mexico have attracted vocal nonlocal groups who are opposed to anything nuclear. The possible future effects of such publically expressed negativism on the Albuquerque Operations Office should be closely observed. Vocal nonlocal intervenors could also be expected in Las Vegas. The impact of such intervention on the nuclear weapons test program has not been evaluated.

The test program is seriously concerned that it could easily lose public acceptance for nuclear weapons testing at NTS if public relations activities are not carefully planned. We believe that the test program should be in a position to participate in matters related to public relations activities of other users of the NTS. We recommend that NV, ANS, and ANE carefully consider and implement a management framework specifically for the joint review of public relations activiites which affect the NTS. Such a framework should include the weapons laboratories, other resident users, and NV. In light of the current SURF and other continued waste activities at NTS, we recommend that such a fraemwork be formally adopted in the very near future.

We recognize that the nontechnical issues raised here are not quantifiable and have not yet been addressed in detail. However, we think that issues such as these are key factors in an evaluation of compatibility and that we should bring them to the attention of ANS where definitive studies can be initiated and the appropriate actions taken.

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3. Data Exchange Working Group, "(Proposed) USERDA Nuclear Weapons Test Ban Treaty," Revision 5, 31 May 1977.

4. Newark, N. M., John A. Blume, and Kanwar K. Kapur, "Design Response Spectra for Nuclear Power Plants," ASCE Structural Engineering Meeting, San Francisco, April 1973.

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6. Murphy, J. R. and J. A. Lahoud, "Analysis of Seismic Peak Amplitudes from Underground Nuclear Explosions, "Bul. Seismological Soc. Am., vol. 59, No. 6, pp 2323-2341, December 1969.

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TABLE I

TEST PROGRAM REAL ESTATE ASSETS AT NTS

AREA	Potentially Acceptable Yield (kt)	Maximum Probable Yield (kt)	# of Available Sites for Yields of $>$90 kt	29-144 kt	0-29	Current Status/ Projected Needs
Active Test Areas						
Yucca Flat	600	250	$<$70	$\sim$240	$\sim$1600	Active/most used area for low & intermediate yields
Pahute Mesa	1000	1000	$\sim$1300			Active/moderate use, high yields
Rainier Mesa	(60)	15(tunnel entry) 60(vert. holes)		$\sim$10	90	Active/DOD effects tests in tunnels
Buckboard Area	750	750	208			Being developed/active in near term, moderate use projected for intermediate to high yields
Currently Inactive Test Areas						
Frenchman Flat	300	250	143	200	316	Past use/highly desirable backup, projected moderate use for low & intermediate yields
Climax Stock	(60)	60		not evaluated		Past use/only NTS area for tunnel tests in hard rock. Future DNA structural effects tests will require hard rock sites
Shoshone Mesa	(50)	6		not evaluated		Past use/first backup for Rainier Mesa for low-yield events
Potential Test Areas						
Gold Meadows Stock	(60)	60		not evaluated		Some exploration/backup for Climax Stock, but less desirable media
Dome Mountain	(60)	60		not evaluated		Field mapping only/could be backup for Rainier Mesa for $>$15 kt
Mid Valley	(250)	250	$>$5 & $<$59	59	238	No drill holes/less desirable than Frenchman for backup
Eleana Area	(100)	100		936 sites, yield spread uncertain		Some exploration/poor formation for weapons testing
Excluded by Data Exchange Working Group						
Jackass Flats	(50)	20	$<$460	460	4023	Past and present use by nonweapons programs/no projected Test Program needs for nuclear weapons

TABLE II

DISTANCES (km) TO GIVEN PEAK VECTOR ACCELERATION

				1.0 g			0.7 g			0.5 g		
PAHUTE	W(kt)	σ_a	σ_R	Med	1σ	2σ	Med	1σ	2σ	Med	1σ	2σ
Tybo	1000	1.30	1.20	2.59	3.11	3.73	3.32	3.99	4.79	4.20	5.04	6.05
	750			2.52	3.02	3.63	3.23	3.88	4.65	4.08	4.90	5.88
Boxcar	1000	1.60	1.36	4.61	6.26	8.52	5.82	7.92	10.77	7.26	9.87	13.43
	750			4.46	6.07	8.25	5.63	7.66	10.41	7.02	9.55	12.98
ERC (Total)[a]	1000	2.30	1.86	3.87	7.21	13.40	5.06	9.40	17.49	6.50	12.09	22.48
	750			3.51	6.53	12.14	4.58	8.52	15.84	5.88	10.94	20.34
	60			1.46	2.72	5.05	1.91	3.55	6.61	2.45	4.56	8.48
YUCCA												
Portmanteau	250	1.32	1.15	1.59	1.83	2.10	1.90	2.19	2.51	2.24	2.58	2.96
Coulommiers	250	1.24	1.12	1.35	1.51	1.69	1.62	1.81	2.03	1.93	2.16	2.42
ERC (Total)[b]	250	2.26	1.81	1.85	3.35	6.06	2.40	4.34	7.86	3.07	5.56	10.06
	50			0.93	1.68	3.05	1.20	2.17	3.93	1.54	2.79	5.05
	5			0.34	0.62	1.11	0.45	0.82	1.47	0.57	1.03	1.87

[a] From ERC equations applicable to Pahute Mesa.
[b] From ERC equations applicable to Yucca and Frenchman Flats.

TABLE III

Approximate Distances Between Candidate Sites For a Terminal Waste Storage Facility and the Closest Boundary of Weapons Testing Areas*

Candidate Sites	Weapons Testing Areas* Yucca Flat	Pahute Mesa	Buckboard Area	Frenchman Flat
Jackass Flat	27.0	37.3 km	20.6 km	18.3 km
Calico Hills	27.0	35.0	15.0	25.4
Skull Mountain	23.8	44.5	26.2	11.1
Climax	**	9.8	17.5	39.7
Eleana	**	13.5	5.6	20.6

Notes:
*not including Rainier Mesa
**Candidate sites are at the edge of testing area

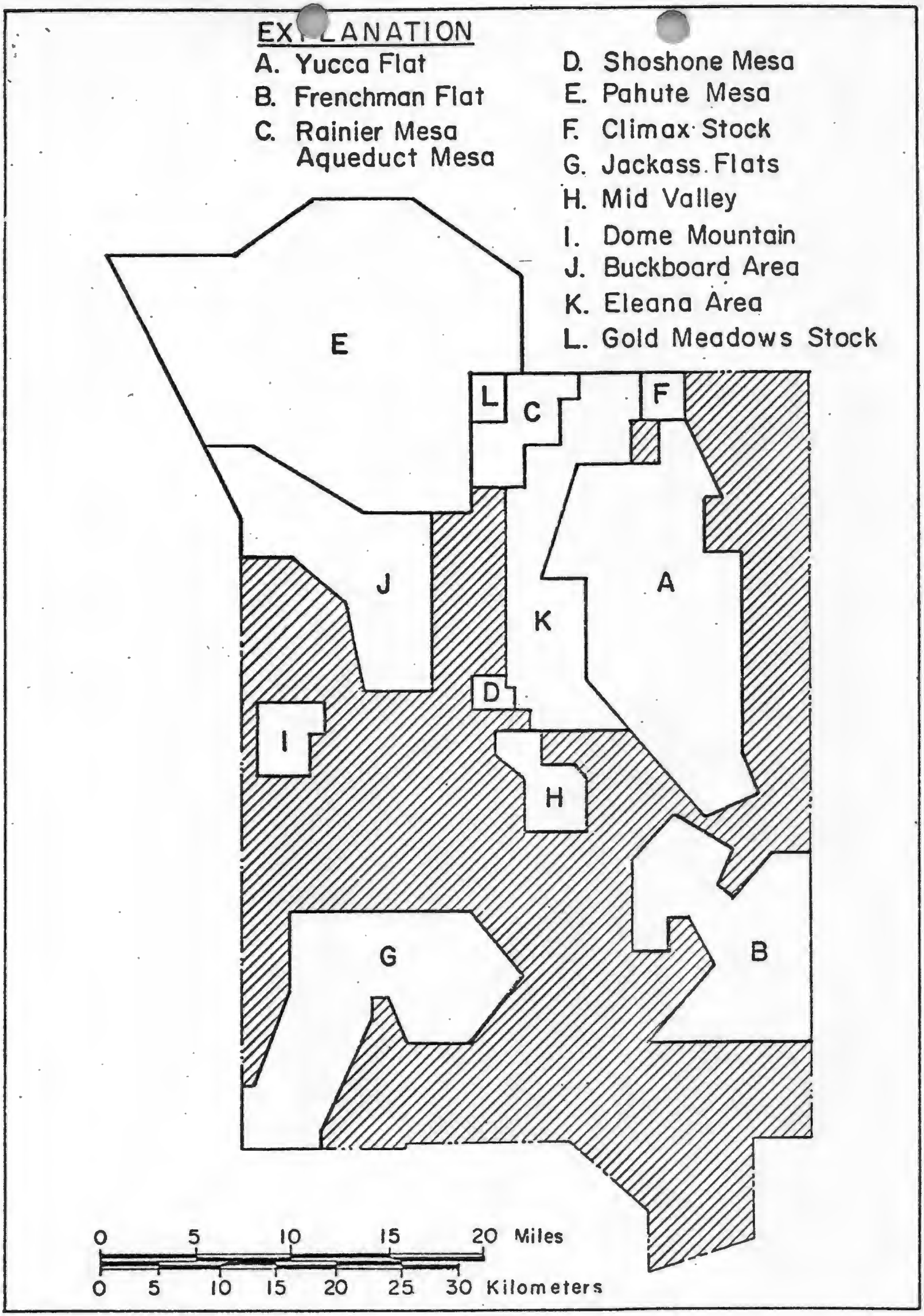
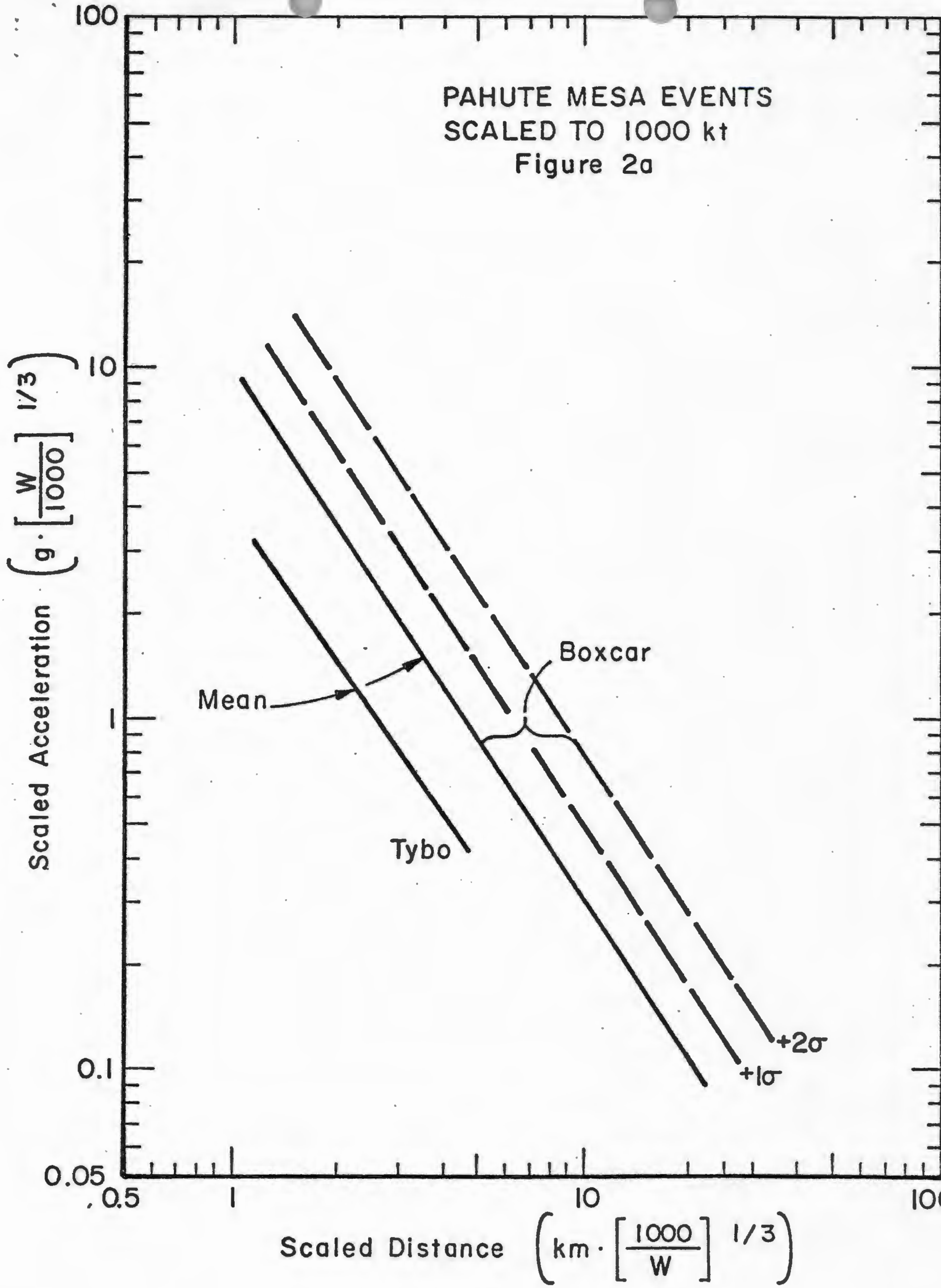
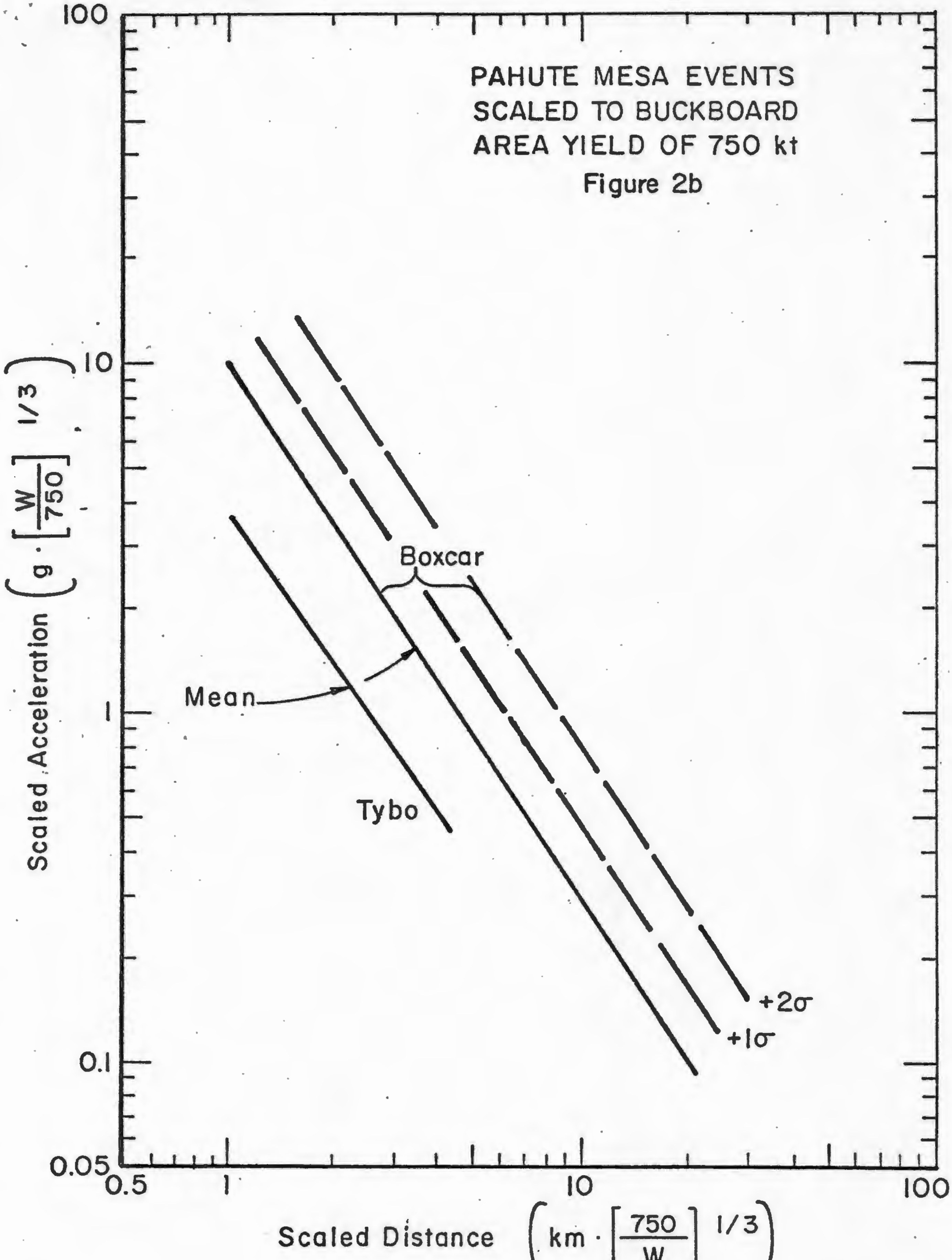


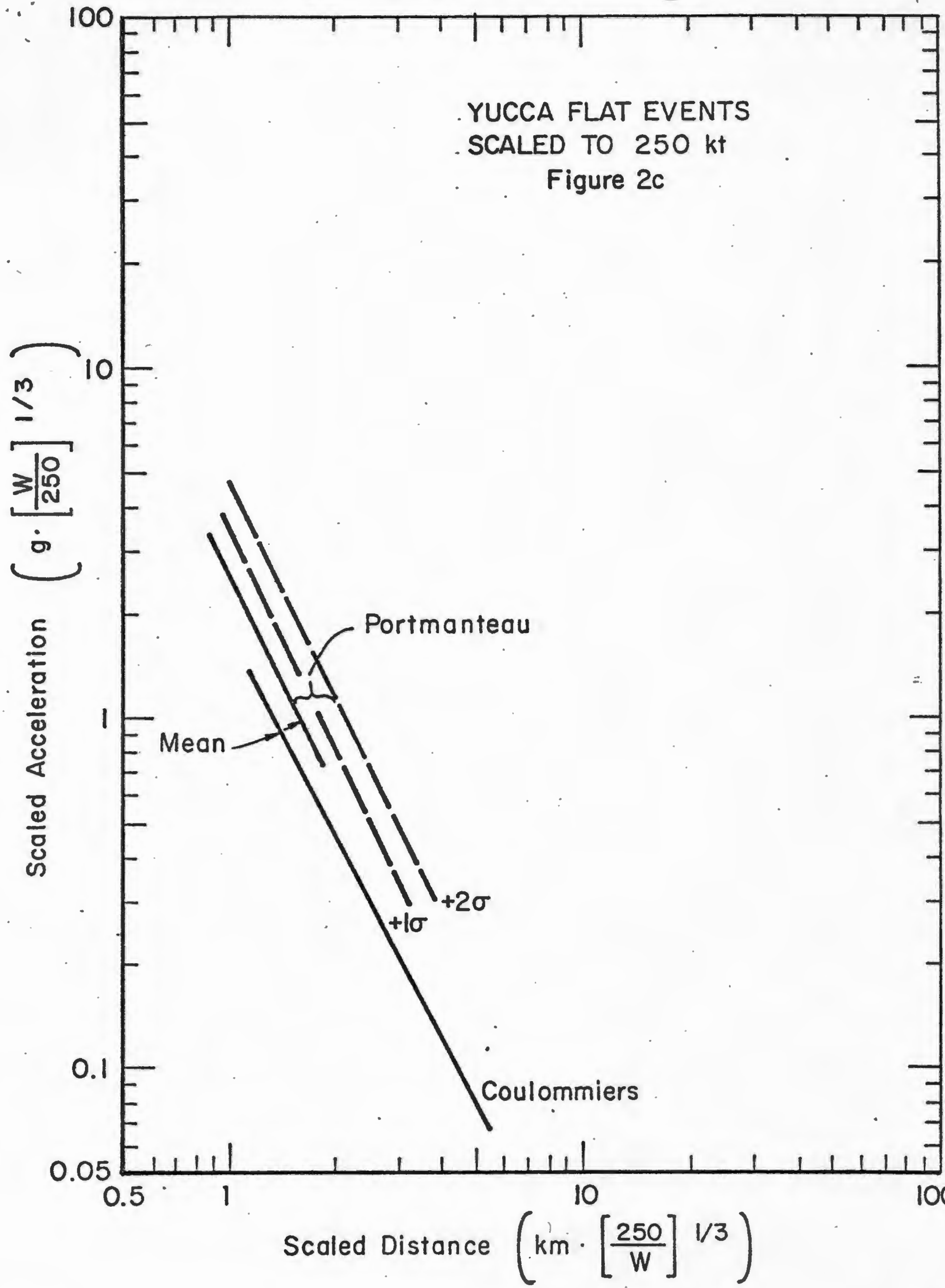
Figure 1

BOUNDARIES OF THE NTS AND ITS TESTING AREAS


PAHUTE MESA EVENTS
SCALED TO 1000 kt
Figure 2a
100
10
1
0.1
0.05
0.5
1
10
100
Scaled Acceleration $\left(g \cdot \left[\frac{W}{1000}\right]^{1/3}\right)$
Scaled Distance $\left(km \cdot \left[\frac{1000}{W}\right]^{1/3}\right)$
Boxcar
Mean
Tybo
+2σ
+1σ

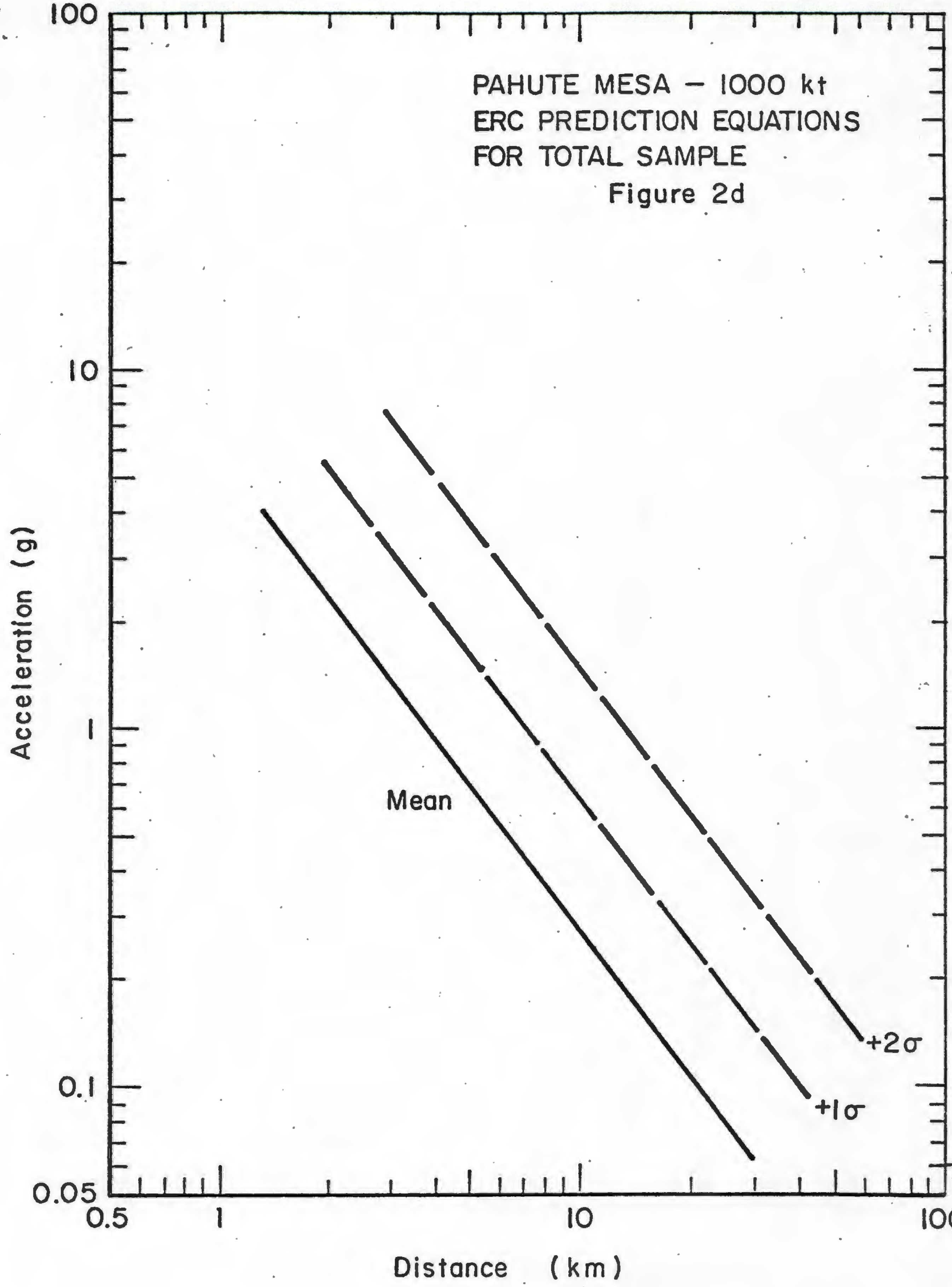
0071 0320


PAHUTE MESA EVENTS
SCALED TO BUCKBOARD
AREA YIELD OF 750 kt
Figure 2b
Scaled Acceleration $\left(g \cdot \left[\frac{W}{750} \right]^{1/3} \right)$
100
10
1
0.1
0.05
0.5
1
10
100
Scaled Distance $\left(km \cdot \left[\frac{750}{W} \right]^{1/3} \right)$
Boxcar
Mean
Tybo
$+2\sigma$
$+1\sigma$

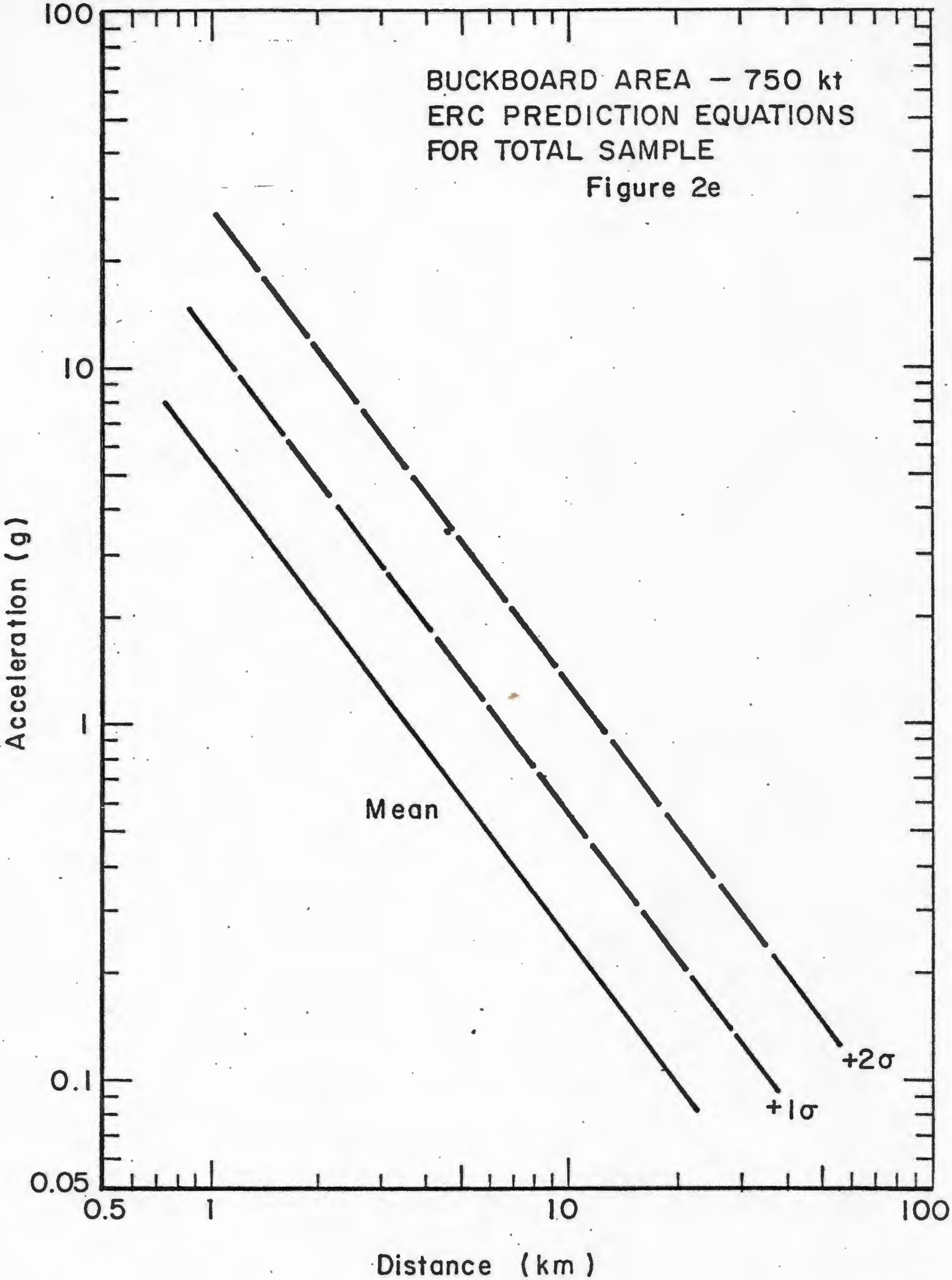


YUCCA FLAT EVENTS
SCALED TO 250 kt
Figure 2c
100
10
1
0.1
0.05
0.5
1
10
100
Scaled Acceleration $\left(g \cdot \left[\frac{W}{250} \right]^{1/3} \right)$
Scaled Distance $\left(km \cdot \left[\frac{250}{W} \right]^{1/3} \right)$
Portmanteau
Mean
+1σ
+2σ
Coulommiers

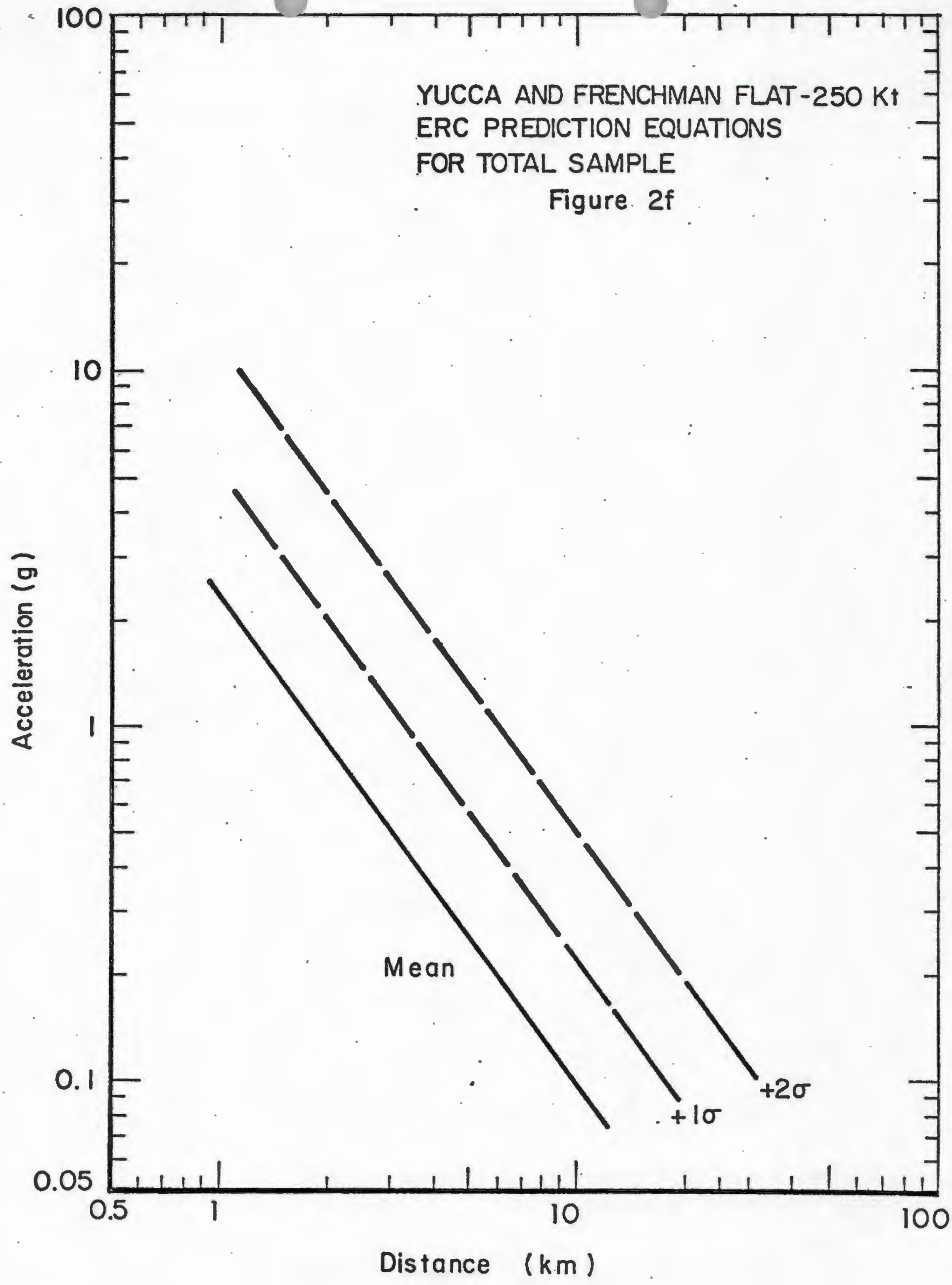
0071 0331



PAHUTE MESA — 1000 kt
ERC PREDICTION EQUATIONS
FOR TOTAL SAMPLE
Figure 2d
Acceleration (g)
100
10
1
0.1
0.05
0.5
1
10
100
Distance (km)
Mean
+1σ
+2σ


BUCKBOARD AREA — 750 kt
ERC PREDICTION EQUATIONS
FOR TOTAL SAMPLE
Figure 2e
100
10
1
0.1
0.05
Acceleration (g)
Mean
+1σ
+2σ
0.5
1
10
100
Distance (km)

0071 0333



YUCCA AND FRENCHMAN FLAT-250 Kt
ERC PREDICTION EQUATIONS
FOR TOTAL SAMPLE
Figure 2f
100
10
1
0.1
0.05
Acceleration (g)
Mean
+1σ
+2σ
0.5
1
10
100
Distance (km)

0071 0334

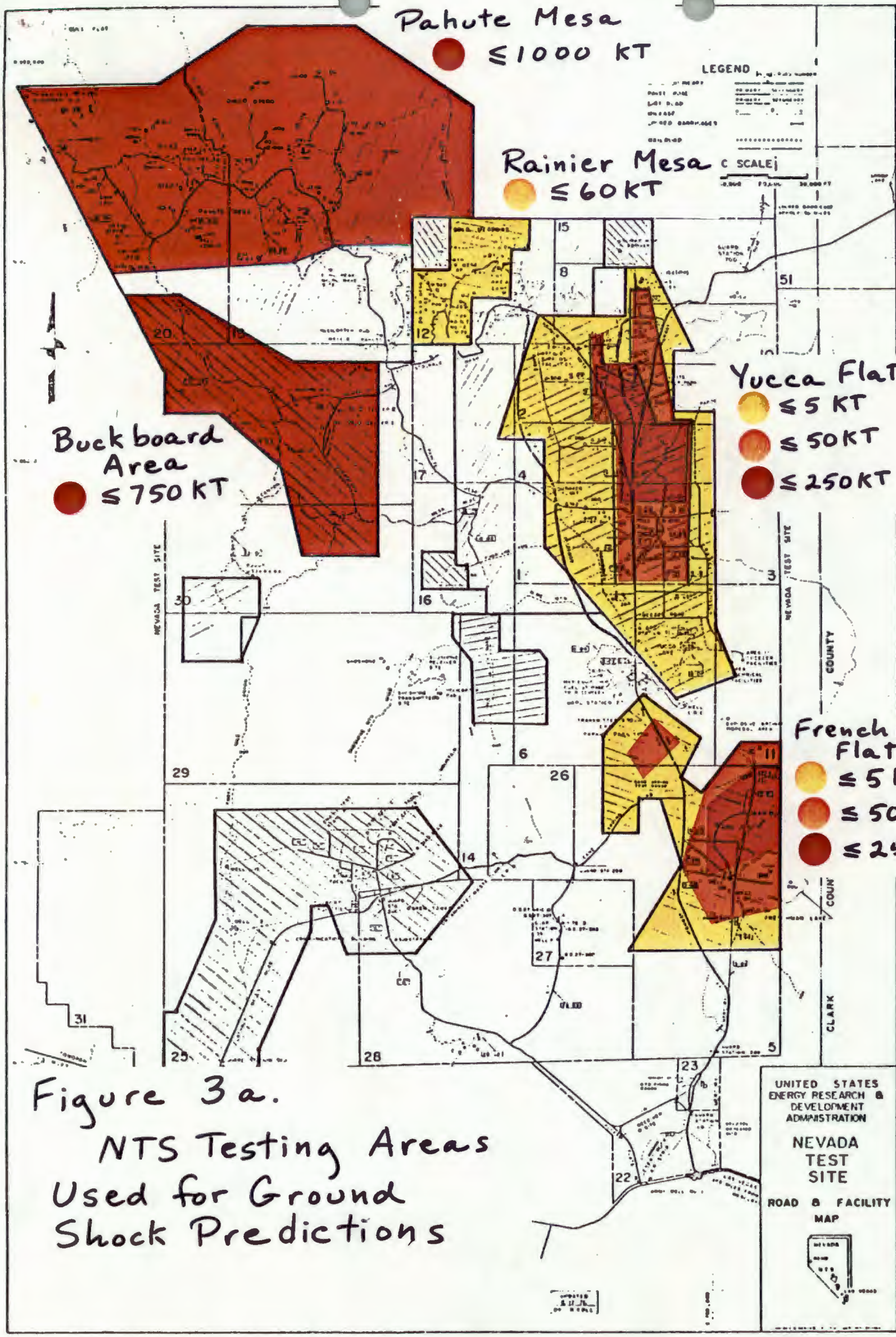


Figure 3a.
NTS Testing Areas Used for Ground Shock Predictions

0071 0335

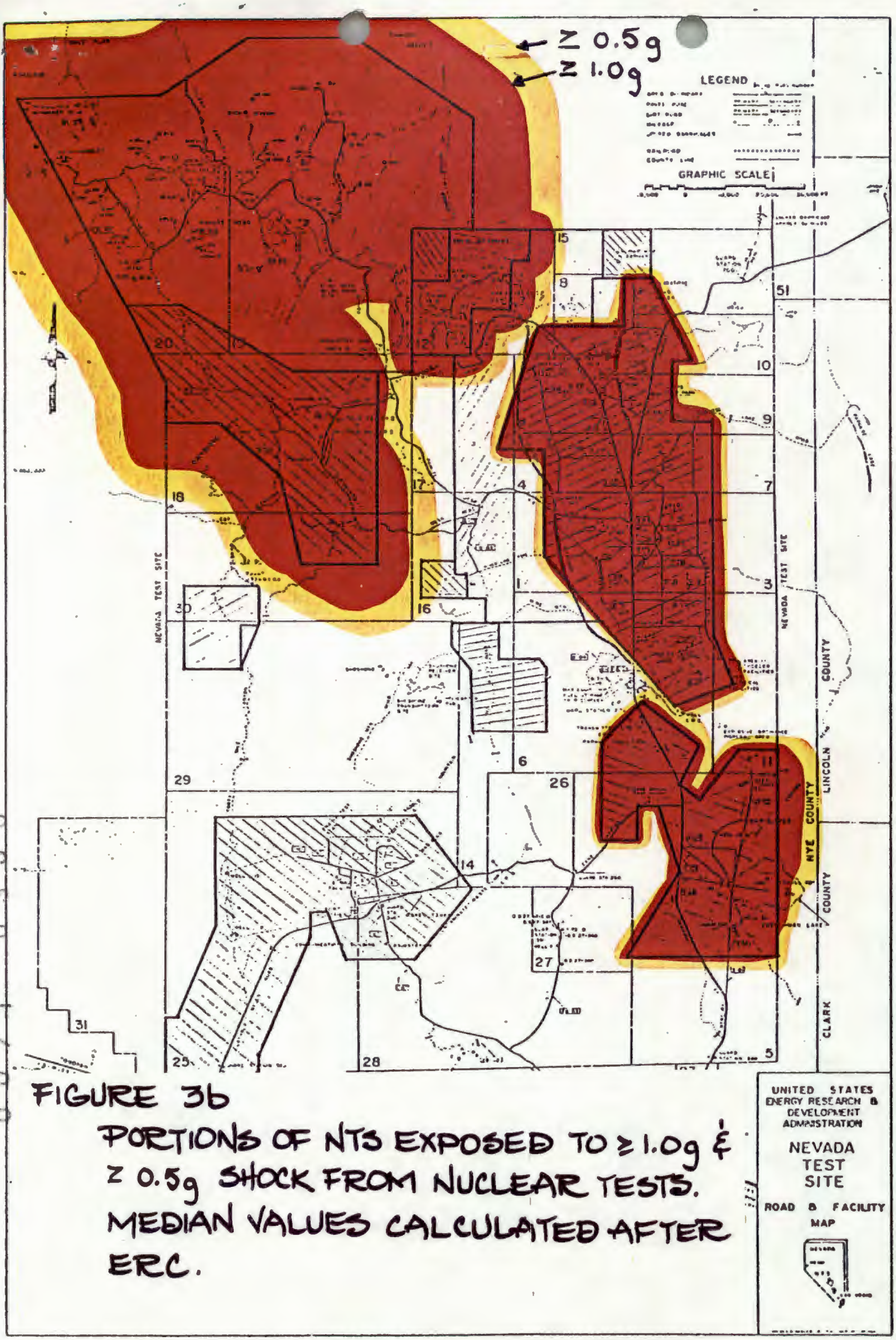


FIGURE 3b
PORTIONS OF NTS EXPOSED TO ≥ 1.0g & ≥ 0.5g SHOCK FROM NUCLEAR TESTS. MEDIAN VALUES CALCULATED AFTER ERC.

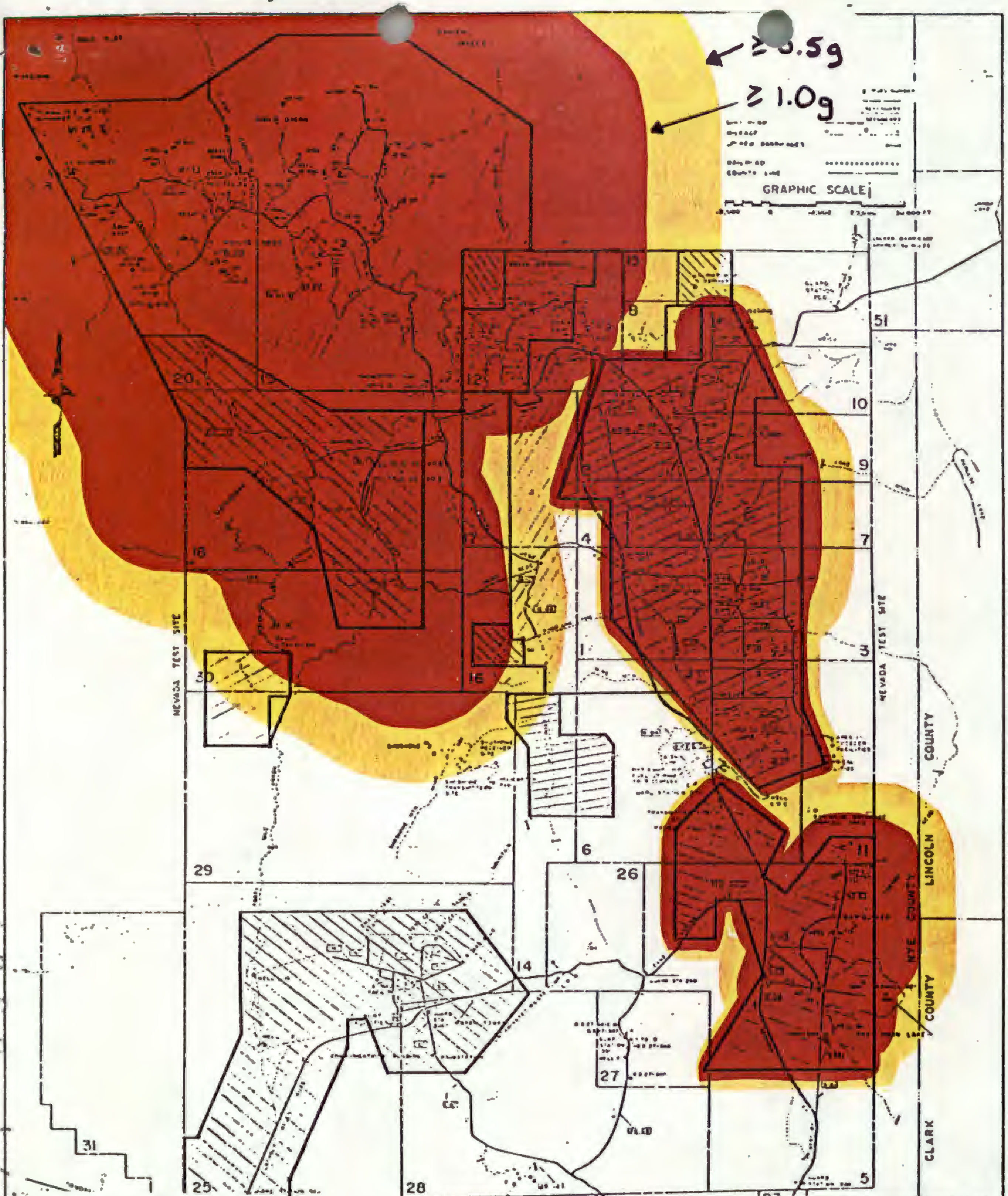


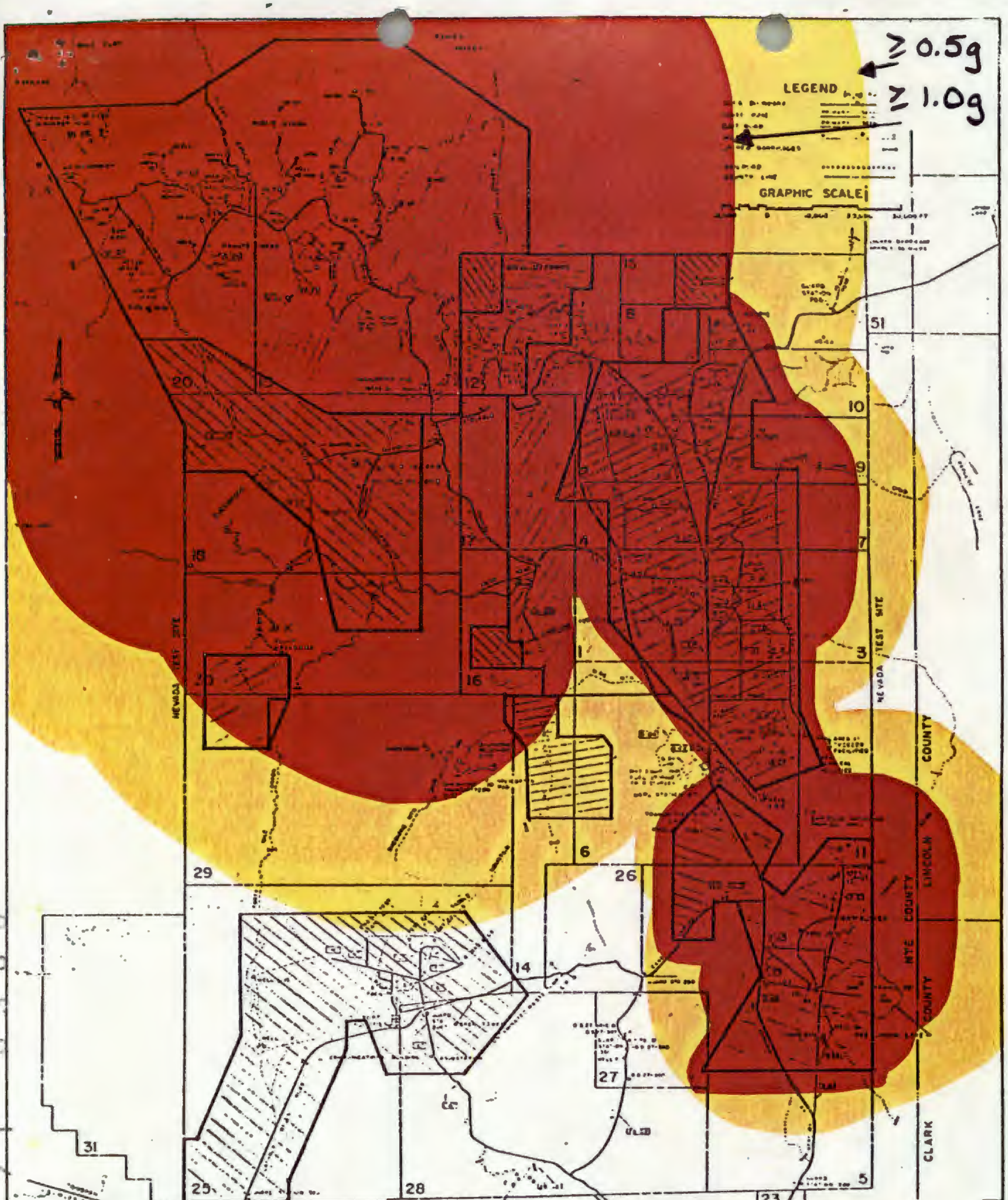
FIGURE 3c

PORTIONS OF NTS EXPOSED TO ≥ 1.0g & ≥ 0.5g SHOCK FROM NUCLEAR TESTS + 1σ VALUES CALCULATED AFTER ERC.

UNITED STATES ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION

NEVADA TEST SITE

ROAD & FACILITY MAP



0071 0338

FIGURE 3d.

PORTIONS OF NTS EXPOSED TO ≥1.0g & ≥0.5g SHOCK FROM NUCLEAR TESTS. + 2 σ VALUES CALCULATED AFTER ERC.