# STUDY OF
# RESERVOIR INDUCED SEISMICITY

## FINAL TECHNICAL REPORT

August 1979

By

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In addition to the major authors to the report, the following people were authors of or contributors to the report. Gregory B. Baecher and Ralph L. Keeney performed the probability analysis based on this data. The theoretical modelling (presented in Capter 3) was prepared and written by Robert J. Withers. The authors for the section of Chapter 4 on Koyna Dam (Lake Shivaji Sagar) in India were Robert E. Harpster, Jon R. Lovegreen, and Lloyd S. Cluff; on Lakes Kremasta and Kastraki in Greece: Jon R. Lovegreen and Robert E. Harpster; on Lakes Eucumbene, Talbingo, and Blowering in Australia: Kenneth D. Weaver and Duane R. Packer; on Lake Benmore in New Zealand: Duane R. Packer and Kenneth D. Weaver; and on Lake Mead in the United States: Kenneth D. Weaver and Robert E. Harpster. Peter L. Knuepfer prepared Appendix A.

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# 1.0 INTRODUCTION

## 1.1 BACKGROUND

As early as 1945, a relationship was recognized between the level of water impounded by Hoover Dam and the rate of occurrence of local earthquakes. Since that time, such relationships have been recognized for other reservoirs around the world. The most commonly cited examples are Kariba in Africa, Koyna in India, and Kremasta in Greece. By the end of 1978, 64 cases of reservoir induced seismicity (RIS) had been reported worldwide (Figure 1-1; Table 1-1). From theoretical and field-oriented studies, various models of the influence of reservoir impoundment on local seismicity have been developed, and factors suspected to influence earthquake activity have been recognized. In particular, a higher occurrence of RIS has been recognized at deep and/or very large reservoirs, as shown on Figure 1-2 (Stuart-Alexander and Mark, 1976; Packer and others, 1977; Stuart-Alexander and others, 1979). However, given the present understanding of RIS, it is not possible to adequately explain why some reservoirs influence seismicity and others do not.

The seismicity induced by reservoir impoundment is an increasingly recognized hazard. A plot of the dates of reservoir impoundment indicates that the number of reservoirs that are deep (depth of greater than 92 m) or are very large (volume greater than $10^{10}$ $m^3$) is rapidly increasing (Figure 1-3). This curve is expected to continue to rise sharply, as over 50 additional deep and/or very large reservoirs are to be completed by 1985.

The number of accepted cases of RIS from among these deep and/or very large reservoirs is also rising. Only a minimum

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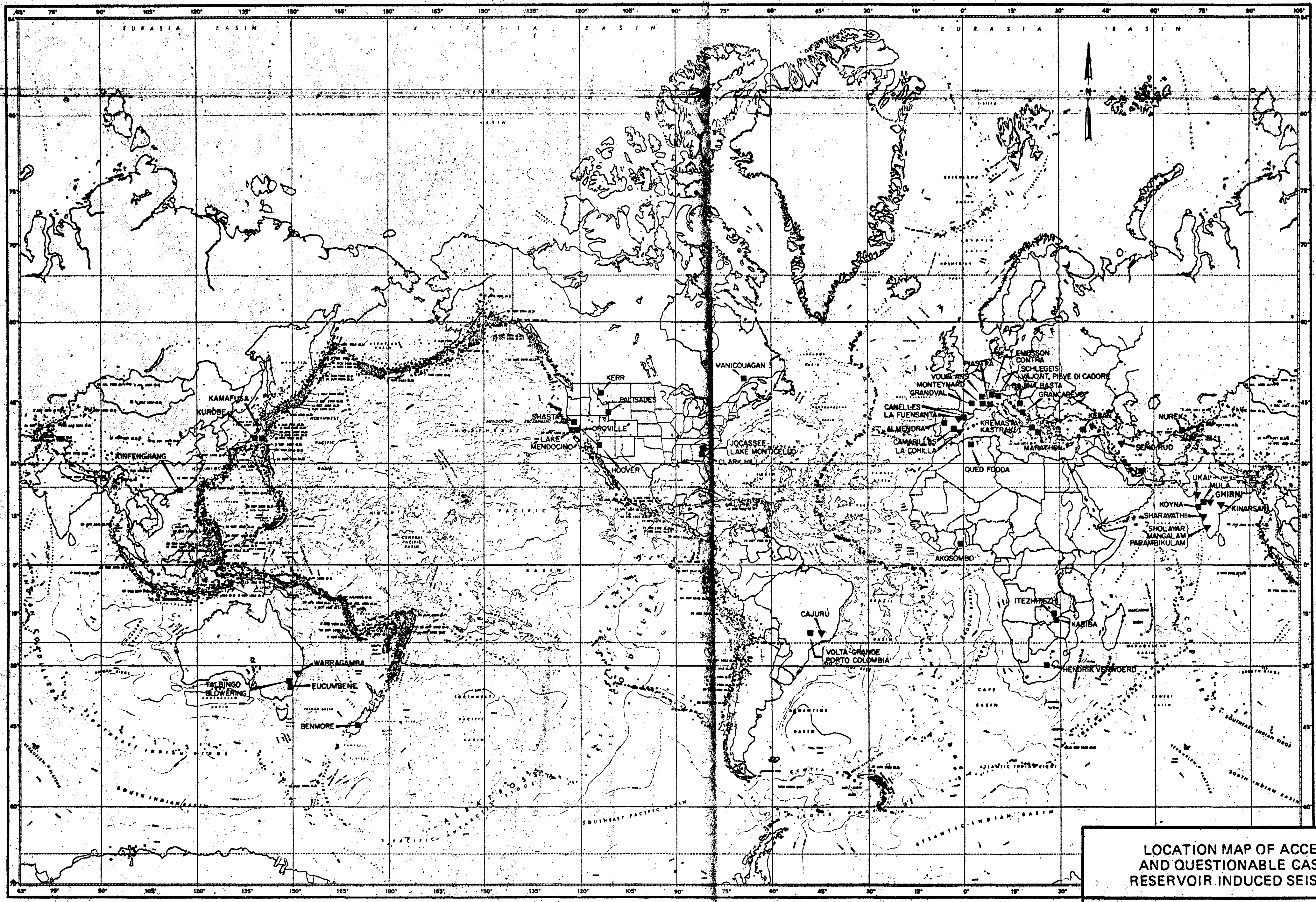

## LOCATION MAP OF ACCEPTED AND QUESTIONABLE CASES OF RESERVOIR INDUCED SEISMICITY

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Figure 1-1

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EXPLANATION

■ Accepted case of RIS ▼ Questionable case of RIS

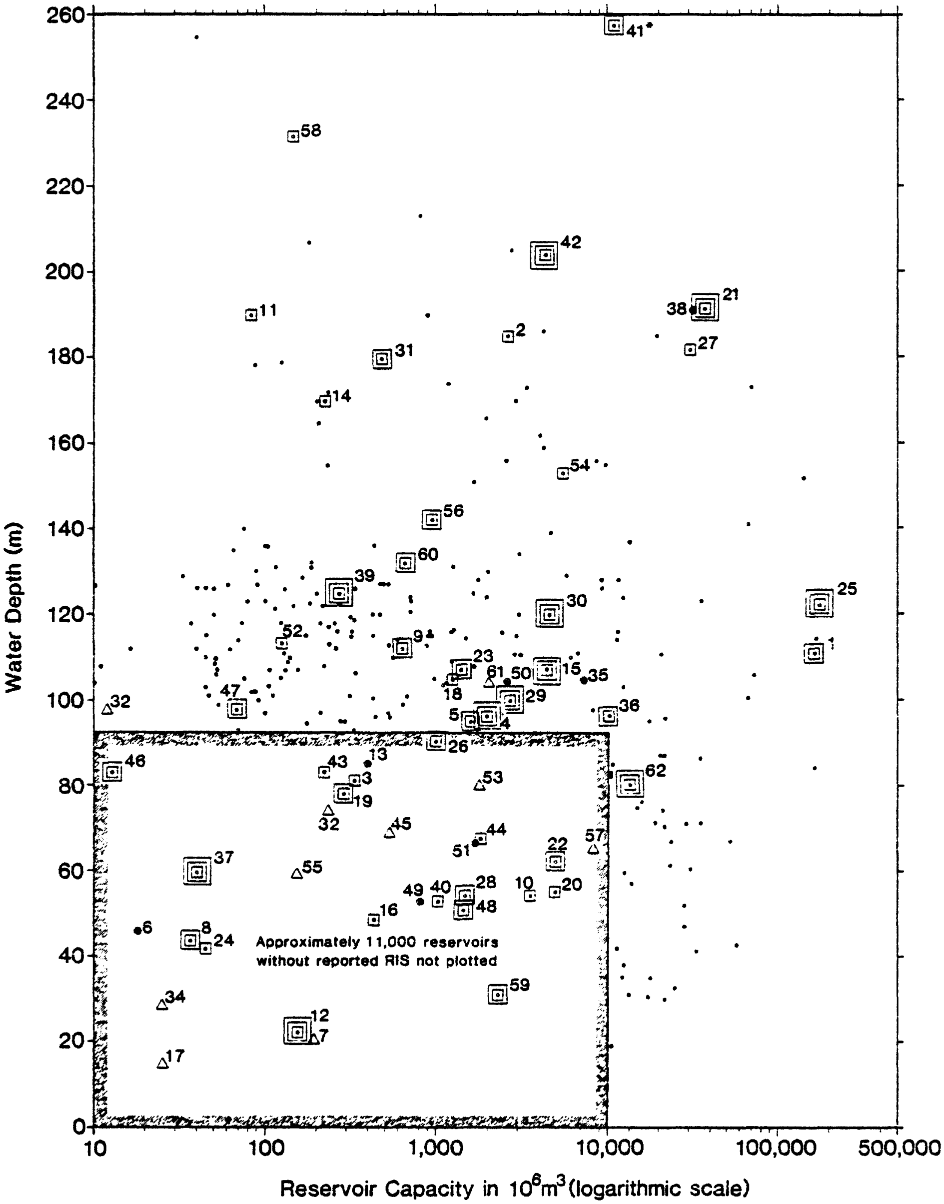
Source: Base map from USGS World Seismicity Map, 1974

# TABLE 1-1

# REPORTED CASES OF RESERVOIR INDUCED SEISMICITY

| No.* | Dam Name, Reservoir Name | Country | Classification of RIS | Magnitude Largest RIS Event |
|---|---|---|---|---|
| 1. | Akosombo Main, Lake Volta | Ghana | Accepted, macro | Intensity V |
| 2. | Almendra, Tormes Reservoir | Spain | Accepted, micro | less than 2 |
| 3. | Bajina Basta | Yugoslavia | Accepted, micro | less than 3 |
| 4. | Benmore | New Zealand | Accepted, macro and micro | 5 (?) |
| 5. | Blowering | Australia | Accepted, macro and micro | 3.5 |
| 6. | Cabin Creek | USA | Not RIS | — |
| 7. | Cajuru | Brazil | Questionable | approx. 4 |
| 8. | Camarillas | Spain | Accepted, macro | 4.1 |
| 9. | Canelles | Spain | Accepted, macro | 4.7 |
| 10. | Clark Hill | USA | Accepted, micro (macro?) | 4.3 (?) |
| 11. | Contra, Lake Vogorno | Switzerland | Accepted, micro | less than 3 |
| 12. | Coyote Valley, Lake Mendocino | USA | Accepted, macro | 5.2 |
| 13. | El Grado | Spain | Not RIS | — |
| 14. | Emosson | Switzerland | Accepted, micro | less than 3 |
| 15. | Eucumbene | Australia | Accepted, macro | 5 (?) |
| 16. | Fairfield, Lake Monticello | USA | Accepted, micro | 2.8 |
| 17. | Ghirni | India | Questionable | — |
| 18. | Grancarevo | Yugoslavia | Accepted, micro | less than 3 |
| 19. | Grandval | France | Accepted, macro and micro | Intensity V |
| 20. | Hendrik Verwoerd | South Africa | Accepted, micro | less than 2 |
| 21. | Hoover, Lake Mead | USA | Accepted, macro and micro | 5.0 |
| 22. | Itezhitezhi | Zambia | Accepted, macro | 4 or less (?) |
| 23. | Jocassee | USA | Accepted, macro and micro | 3.2 |
| 24. | Kamafusa | Japan | Accepted, micro | less than 3 |
| 25. | Kariba | Zambia/Rhodesia | Accepted, macro and micro | 6.25 |
| 26. | Kastraki | Greece | Accepted, macro | 4.6 |
| 27. | Keban | Turkey | Accepted, micro | less than 3 |
| 28. | Kerr, Flathead Lake | USA | Accepted, macro | 4.9 |
|  | Kinarsani | India | Questionable | — |
| 29. | Koyna, Shivaji Sagar Lake | India | Accepted, macro and micro | 6.5 |
| 30. | Kremasta | Greece | Accepted, macro and micro | 6.3 |
| 31. | Kurobe | Japan | Accepted, macro and micro | 4.9 |
| 32. | La Cohilla | Spain | Questionable | — |
| 33. | La Fuensanta | Spain | Questionable | — |
| 34. | Mangalam | India | Questionable | — |
| 35. | Mangla | Pakistan | Not RIS | — |
| 36. | Manicouagan 3 | Canada | Accepted, macro and micro | 4.1 |
| 37. | Marathon | Greece | Accepted, macro | 5.75 |
| 38. | Mica | Canada | Not RIS | — |
| 39. | Monteynard | France | Accepted, macro | Intensity VII |
| 40. | Mula | India | Accepted, micro | less than 1 |
| 41. | Nurek | USSR | Accepted, macro and micro | 4.5 |
| 42. | Oroville | USA | Accepted, macro | 5.7 |
| 43. | Oued Fodda | Algeria | Accepted, micro | less than 3 |
| 44. | Palisades | USA | Accepted, micro | 3.7 (?) |
| 45. | Parambikulam | India | Questionable | — |
| 46. | Piastra | Italy | Accepted, macro and micro | 4.4 |
| 47. | Pieve di Cadore | Italy | Accepted, macro and micro | Intensity V |
| 48. | Porto Colombia | Brazil | Accepted, macro | — |
| 49. | Rocky Reach | USA | Not RIS | — |
| 50. | San Luis | USA | Not RIS | — |
| 51. | Sanford | USA | Not RIS | — |
| 52. | Schlegeis | Austria | Accepted, micro | less than 2 |
| 53. | Sefid Rud | Iran | Questionable | 4.7 |
|  | Sharavathi | India | Questionable | — |
| 54. | Shasta | USA | Accepted, micro | less than 3 |
| 55. | Sholayar | India | Questionable | — |
| 56. | Talbingo | Australia | Accepted, macro and micro | 3.5 |
| 57. | Ukai | India | Questionable | — |
| 58. | Vajont | Italy | Accepted, micro | less than 3 |
| 59. | Volta Grande | Brazil | Accepted, macro | less than 4 |
| 60. | Vouglans | France | Accepted, macro | 4.4 |
| 61. | Warragamba, Lake Burragorang | Australia | Questionable | 5.4 |
| 62. | Xinfengjiang | China | Accepted, macro and micro | 6 |

*Numbers correspond to numbers on Figure 1-2; Kinarsani and Sharavathi are unplotted because of insufficient data.



Note: The following reservoirs were not plotted because of insufficient data: Kinarsani, Sharavathi.

*41 - Nurek (USSR) depth is in excess of 285 m.

EXPLANATION:

| | |
|---|---|
| · | Deep and/or very large reservoir |
| ▣ | Accepted case of RIS, maximum magnitude ≥ 5 |
| ▣ | Accepted case of RIS, maximum magnitude 3-5 |
| ▣ | Accepted case of RIS, maximum magnitude ≤ 3 |
| △ | Questionable case of RIS |
| ● | Not RIS |

## PLOT OF DEPTH AND VOLUME FOR DEEP AND/OR VERY LARGE RESERVOIRS AND REPORTED CASES OF RIS

| | |
|---|---|
| Project No. 14087A | Figure 1-2 |
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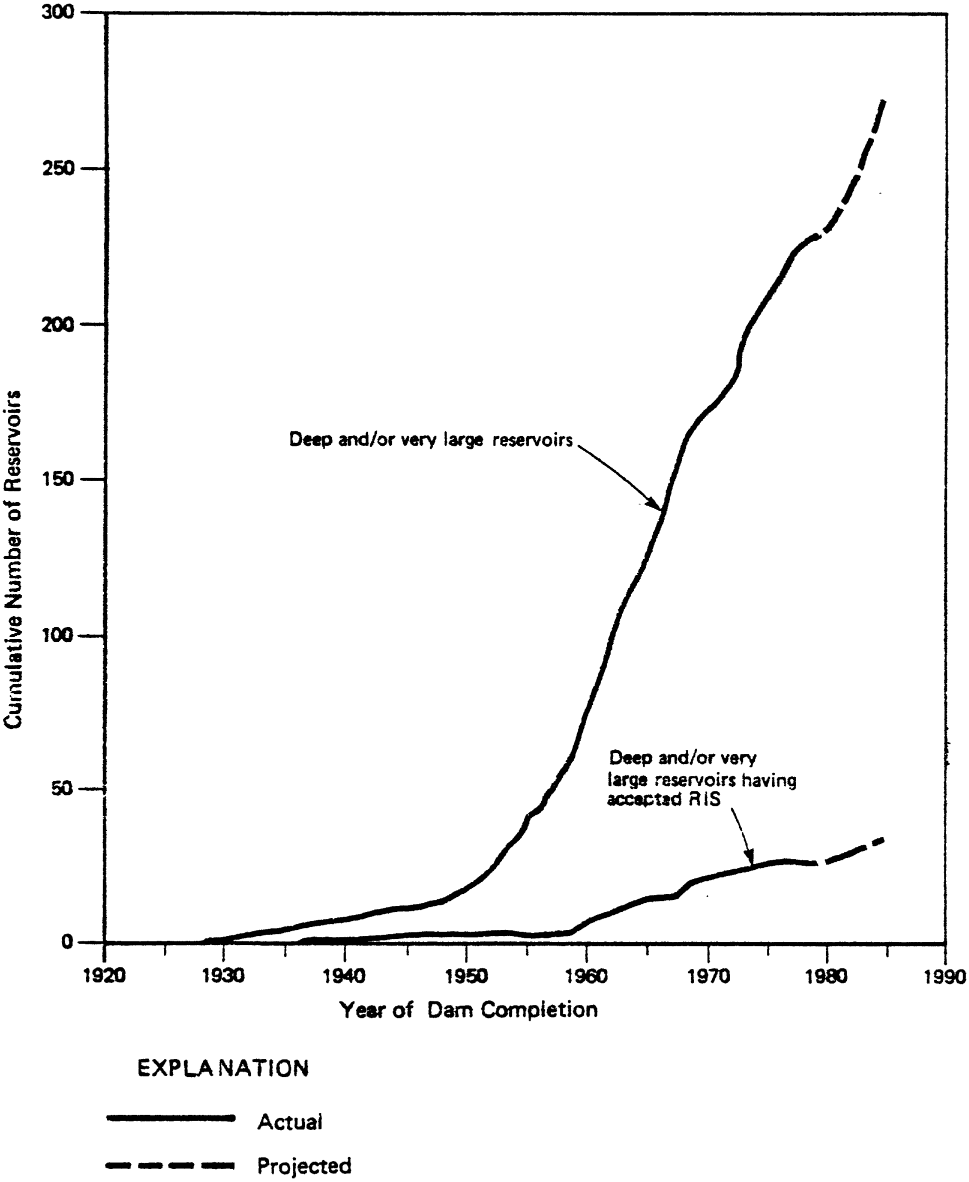

CUMULATIVE NUMBER OF DEEP
AND/OR VERY LARGE RESERVOIRS
BY YEAR OF DAM COMPLETION

| Project No. 14087A | Figure 1-3 |
|---|---|
| **Woodward-Clyde Consultants** | Page 5 |

number of actual cases of RIS have been studied because occurrence of RIS events is often delayed following reservoir completion, and no comprehensive examination of the world's reservoirs for evidence of RIS has been made. A 5-year projection of the curve showing the occurrence of RIS for deep and/or very large reservoirs over the past 20 years (shown on Figure 3-1) suggests that, among these reservoirs, approximately 10 more cases of RIS are likely to occur. The historic record indicates the potential for at least some of these RIS events to be sufficiently large to cause damage; in addition, some may occur in areas of low historical seismicity, where structures are not designed for damaging earthquakes.

## 1.2 PURPOSE OF STUDY

This report presents the findings and accomplishments resulting from a study of reservoir induced seismicity undertaken by Woodward-Clyde Consultants for the Earthquake Hazards Reduction Program of the United States Geological Survey. The objectives for this study have been: 1) to evaluate geologic, seismologic, and hydrologic factors in order to make more meaningful and confident evaluations of the potential for RIS; 2) to develop a more reliable method for evaluating the potential for RIS at existing and proposed reservoir locations throughout the world; and 3) to evaluate the theoretical, seismological, and rock mechanics base of RIS. A large quantity of data on the deepest and largest of the world's reservoirs has been gathered and analyzed.

These data and derived conclusions have been organized in this report into three sections and two appendices. The first section (Section 2) describes data collection and the probabilistic assessment of reservoir induced seismicity. Selected examples are used to illustrate the assumptions and techniques employed to categorize the reported cases of resevoir induced seismicity. Preliminary probabilistic models of RIS are presented and discussed. The second section (Section 3) is a description of theoretical modelling of reservoir induced seismicity. A number of models and the parameters used in these models are discussed. The third section (Section 4) presents the results of reconnaissance geologic studies of five areas that had reservoir induced seismic events of magnitude 5 or greater. The first appendix presents the data collected on deep and/or very large reservoirs and reported cases of RIS. The second appendix includes seismicity catalogs for four selected cases of RIS reviewed in Section 2.

The scope of this study consisted of the collection of data on over 250 reservoirs. However, because the size of the data sample is limited, a one-sided consideration of some data has resulted. One example of such bias involves the accepted cases of RIS. It is highly probable that the number of cases of RIS reported in the literature underestimates the total number of cases that have actually occurred; this is particularly true for reservoir induced microseismicity, which generally would go undetected except where microearthquake recording networks are established around a reservoir. Furthermore, the scope of this study did not allow evaluation of whether or not a temporal and spatial association of seismicity with the reservoir filling history was present at each of the 234 deep and/or very large reservoirs. Thus, the accepted number of RIS cases may underestimate the number of actual occurrences.

Another similar bias exists in the evaluation of active faults that have had displacement in the present tectonic regime at those reservoirs that have had a reservoir induced seismic event of magnitude greater than or equal to 5. It was beyond the scope of this study to evaluate how many of the other reservoirs (with or without reservoir induced seismicity) have active faulting within the hydrologic regime of the reservoir. The results of these studies, though "biased," do provide some basis for conclusions. For example, the existence of reservoirs that 1) do not have active faults within their influence, and 2) have RIS events with surface fault rupture would suggest that reservoirs could induce surface faulting where the tectonic regime had not. Future studies of reservoir induced seismicity could be directed toward gathering the data needed to evaluate further some of these areas of bias.

# 2.0 DATA COLLECTION AND PROBABILISTIC ASSESSMENT OF RESERVOIR INDUCED SEISMICITY

## 2.1 INTRODUCTION

A search of available literature was made for cases of reservoir induced seismicity (RIS) reported as of the end of 1978. In addition, information was compiled on deep (maximum water depth of 92 m or greater) and/or very large (maximum water volume of $10^{10}$ $m^3$ or greater) reservoirs completed as of the end of 1975. The data compiled for each reservoir are presented in Appendix A.

Deep and very large reservoirs were chosen as the base for this study because a relatively higher percentage of these reservoirs exhibit induced seismicity than do smaller or shallower reservoirs (Packer and others, 1977; Stuart-Alexander and Mark, 1976) and because data were expected to be relatively more available on these large engineering works. Data were gathered for a large number of parameters, including reservoir size and shape, water impoundment and fluctuation history, regional and local geology, stress conditions and faulting, hydrology, and seismicity. A complete list of these parameters is presented in Table A-1 of Appendix A.

The data compilation studies had a three-fold purpose: 1) to update and expand existing data collections on reported cases of reservoir induced seismicity; 2) to establish a consistent yet manageable data base for a probabilistic analysis of the interrelationships between certain geologic, hydrologic, and seismologic parameters and the occurrence of reservoir induced seismicity; and 3) to develop a preliminary statistical model capable of predicting the probability of RIS occurrence at an existing or proposed reservoir site.

This section of the report provides a summary of the procedures used for the data collection program, a summary and examples of the procedures used to classify reported RIS cases, results of statistical analysis, and information on a preliminary statistical model for predicting the probability of occurrence of reservoir induced seismicity.

## 2.2 DATA COLLECTION PROGRAM

The procedures followed in the evaluation of the data for each group of parameters are described below.

### 2.2.1 General Reservoir Parameters

The general parameters of interest to this study include dam and reservoir name, location (country), geographic province, river, type of dam, year of completion, dam height above lowest foundation, maximum water depth and volume, length of dam, and use of reservoir. Information on most of these parameters was obtained from the World Register of Dams, supplemented by more recent compilations such as Mermel (1978) and Simpson (1976).

Reservoirs were located on atlas maps and other available maps, and the latitude-longitude coordinates and maximum reservoir dimension were measured directly. The location of the center of the reservoir was calculated as that point (within the reservoir) closest to the midpoint of a line connecting the farthest extremities of the reservoir.

Information on reservoir filling histories, when available, was categorized according to rates and duration of initial filling as well as maximum drawdown and refilling. (Initial filling is defined for this study as filling to 90 percent of the maximum water level.) The use of the reservoir can provide a qualitative estimate of typical water-level fluctuations. Flood control reservoirs tend to be held at relatively low levels during most of their lifetime, except during floods when they rapidly fill. Irrigation reservoirs generally undergo cyclic (seasonal) water level variations. Hydropower reservoirs normally are held at relatively constant levels, as are reservoirs used for public water supply. For multi-purpose reservoirs, the first use listed in the World Register of Dams was chosen, on the assumption that it is the primary use of the reservoir.

Reservoirs were classified according to maximum water depth rather than dam height because water depth is directly related to the stress imposed by a reservoir. Maximum water depths were obtained from engineering reports and publications where available. In many cases, water depths were calculated from detailed dam cross sections or topographic maps showing reservoir outlines. Where direct information on maximum water depth was unavailable, the depth was estimated from dam height and type. Formulae similar to those discussed by Packer and others (1977) were used for these estimations and different formulae were used depending on the type and height of the dam: for concrete dams greater than 150 m in height, 30 m was subtracted from the dam height; for concrete dams between 100 m and 150 m in height, 18 m was subtracted from the dam height; for concrete dams less than 100 m in height, the dam height was multiplied by 0.9; for earth or rock dams greater than or equal to 100 m in height, the dam height was multiplied by 0.95; and for earth or rock dams less than 100 m in height, the dam height was multiplied by 0.9.

### 2.2.2 Geologic Parameters

The geologic parameters include regional and local geology, tectonic province and stress regime, and orientation and degree of structural deformation. Geologic maps, local and regional geologic studies, engineering reports, and literature on tectonics were examined to obtain these parameters for each reservoir.

Geologic Conditions - Based on interpretations of site-specific geologic maps or descriptions and/or regional geologic maps, the geology of a reservoir area was characterized as coarse clastic, fine clastic, carbonate, metamorphic, batholithic, or volcanic. Where more than one rock type is present, the geology was characterized by the most prevalent rock type. The coarse clastic characterization includes conglomerate and sandstone. The fine clastic classification includes siltstone, claystone, and shale. Carbonate includes limestone, dolomite, marl (using European designation), and evaporites. Metamorphic includes all metamorphic rocks, such as marble, gneiss, and schist. Batholithic includes intrusive rocks, such as granite, gabbro, diorite, and porphyry (Russian usage). Volcanic includes extrusive rocks, such as basalt, andesite, and tuff.

Regional Stress Regime - The tectonic stress in the region of a reservoir was characterized as extensional (normal), shear (strike-slip), or compressional (thrust). The type of tectonic stress active in an area was classified from focal mechanisms of shallow local or regional earthquakes, from sense and distribution of young surface faults, and/or from general plate tectonics models. The method used in the stress classification, as well as a ranking of confidence level for that classification, is indicated for each reservoir. The highest levels of confidence are applied to those cases in which site-specific stress indications are available, such as focal mechanisms for earthquakes located at or very near the reservoir. The lowest levels of confidence are assigned to classifications resulting from poorly understood tectonic interpretations, such as those in shield areas for which little or no earthquake data exist and in which young faults have not been recognized.

Recent studies, such as Sykes (1978), suggest that areas traditionally considered tectonically "stable" are in fact undergoing compressional tectonic stress. Sykes (1978) demonstrates such compression for portions of South America, Africa, and Asia from fault distributions and limited focal mechanism data. Other focal mechanism studies of "stable" areas have yielded similar results; for example, the work by Leblanc and Anglin (1978) at the Manicouagan-3 reservoir in Canada has demonstrated compressive focal mechanisms. Focal mechanism solutions by Chandra (1977) for the Indian Peninsula indicate that shear tectonic stress, accompanied by compression, characterizes the tectonics of this intraplate region.

Degree of Structural Deformation - The degree of structural deformation of a region was assessed from geologic maps that indicate the attitudes of beds or foliation. Deformation of regions was characterized as flat-lying, shallow-dipping, steeply dipping, vertical, overturned, or strongly deformed. For example, shallow-dipping areas are those in which the characteristic dip is 35 degrees or less; conversely, strongly deformed areas are those in which strata are severely folded and faulted.

### 2.2.3 Faulting Parameters

Information on the geometry, style, and age of faulting near each reservoir was considered independently of other geologic conditions. To localize the study of faulting and seismicity in the vicinity of a reservoir, a procedure was adopted in which a circle is projected about the center of the reservoir, with the radius equal to the longest dimension of the reservoir. This circle is used to define the boundary of the "local area" of a reservoir. Such a circle is consistent with theoretical models of the influence of reservoir loading on the underlying crust (Withers and Nyland, 1978).

The predominant style of faulting was assessed for each reservoir local area from local geologic maps (when available). Faults in an area are predominantly either dip-slip, strike-slip, or oblique-slip. Where more than one type of fault is present, the type of faulting was characterized by those faults showing evidence of most recent activity. Similarly, information was gathered on the azimuth, dip, length, name, and distance of the most recently active fault in the local area of a reservoir. Where no faults are mapped in the reservoir local area, faults within the surrounding tectonic province were considered in assessing the style of faulting.

For this data compilation study, faults were considered active (or "young") if the literature cited evidence of displacement occurring during the active tectonic regime. Although this definition of active faults is broader than most definitions in common use in the United States, it is more applicable to worldwide studies of faults, where detailed information on Late Quaternary displacements may be lacking.

For the assessment of the recency of fault activity, at least three complicating factors were considered. First, inactive bedrock faults can have a different type of faulting than recently active faults, due to changes in stress conditions over time. In particular, reactivated faults may have a different sense of displacement than they had during their previous tectonic environment. Examples include the Foothills fault system of California, a former compressional subduction zone undergoing present-day extension (Schwartz and others, 1979), and certain faults in West Africa, formerly transform faults that are now undergoing extensional displacement (Burke, 1971). Secondly, active faults may differ in their degree of activity. The slip rate and recurrence intervals of various faults may differ by several orders of magnitude, and maximum earthquake magnitude and slip per event may also differ substantially. Finally, the amount of tectonic stress accumulation along a fault is a significant factor to consider in the assessment of the probability of reservoir induced seismicity. A fault that has a large amount of stress accumulation would more likely be affected by reservoir impoundment than a fault that has ruptured recently and along which stress has not yet accumulated to near-critical levels. However, within the scope of this study, it was not possible to fully assess the significance to the occurrence of RIS of these three considerations.

### 2.2.4 Hydrology Parameters

Limited information on hydrologic conditions at reservoirs was compiled, when available, from engineering and geologic literature examined in this review. Of particular interest was information on rock permeability beneath and adjacent to reservoirs. Ideally, the permeability information required would include data on near-surface permeability as well as on pore pressures in rocks at depth. In practice, such information can rarely be obtained. However, knowledge of the topographic relief of an area and on rock types present and their probable permeability could be used to roughly estimate the influence of reservoir impoundment on pore-water pressures. Because data were available for only a few of the reservoirs, no statistical assessment of hydrologic parameters was attempted.

### 2.2.5 Seismicity Parameters

Information on the seismicity in the vicinity of each reported RIS case was gathered from worldwide data sources. These sources, which were available from the Woodward-Clyde Consultants' Earthquake Data Bank, included the International Seismological Centre (ISC) and the National Oceanographic and Atmospheric Administration (NOAA) listings. These data were supplemented with published reports of local seismicity. The published literature was the only source of data on microearthquakes, since such events are generally too small to be included in the ISC or NOAA catalogs.

The seismic data were classified as either "macro" or "micro." Typically, the cut-off between macro and micro is placed at magnitude 3. However, for the purpose of this study, the distinction between macro and micro was based primarily on the source of the data: if the earthquake was reported in NOAA or ISC catalogs with a magnitude greater than 3, it was classified as macro; if the earthquake was reported only from other souces with magnitudes less than 3, or with felt reports for only a very small area, it was classified as micro. The NOAA and ISC catalogs typically include all events above magnitude 4 to 5. In practice, seismographic coverage and reporting vary depending on the area being investigated; therefore, a magnitude cut-off to distinguish between macro and micro events differs in each of the RIS cases investigated.

Although a number of seismic parameters were defined for this study (see Appendix A, Table A-1), many values were not assigned. These include "b" values near the reservoir compared to the background level, and the variation of "b" within the tectonic province of the reservoir. Evaluations of the number of seismic events per unit area and the amount of energy release were discontinued as the data were collected because such evaluations were found not to be feasible for two reasons:

1. It was difficult to define the boundaries of the tectonic province in which the reservoir occurred because of concentrated epicenters along boundaries. This was particularly difficult when the reservoir was on the edge of a seismic belt. Moreover, a quick decision to include or exclude major seismic features would lead to misleading or incorrect conclusions.

2. The initial plan was to use published catalog data to assess if the seismicity near the reservoir had changed in some way after the reservoir had filled. A thorough assessment involves a comparison of energy release, rate of occurrence, and "b" slope for seismicity local to the reservoir with that for the entire tectonic province, and a further comparison of these factors before and after reservoir filling. In general, the quality of data proved to be too poor to allow such rigorous analysis. Accordingly, only generalized characterizations of seismicity changes were made (Table 2-1).

The data that were collected for several parameters were based on the seismicity catalogs, plots of seismicity, and histograms of the time of occurrence for events within one and three radii of the reservoir center. The date of the first probable RIS event was selected based upon a knowledge of the pre-impoundment seismicity or upon local microseismicity data. The date and magnitude of the largest reservoir-induced earthquake was also estimated from this data.

The increased resolution and detection capabilities of worldwide seismic networks over the past few years, particularly since 1964, has considerably improved the quality of data reported in the ISC and NOAA catalogs, and a greater number of magnitude values are being reported. However, prior to 1964, many large events listed in these catalogs have no reported magnitudes. Therefore, published reports of particular reservoir induced events were extremely useful in the selection of the maximum earthquake magnitude.

## 2.3 CATEGORIZATION OF RIS

### 2.3.1 Procedure

Among the cases of reservoir induced seismicity (RIS) reported in the literature, some are clearly associated with reservoir impoundment, and others appear to be unrelated to the reservoir impoundment. For a statistical evaluation of RIS, those seismicity cases that are judged to be reservoir induced must be distinguished from those that apparently are not. Accordingly, a set of criteria were established to provide a systematic evaluation of each reported case of RIS.

The influence of a reservoir on the seismicity of the local area was evaluated for each of 64 reported cases of RIS (Table 1-1). Three categories were identified: accepted cases of reservoir induced seismicity, questionable cases of reservoir induced seismicity, and cases of seismic activity near reservoirs that were not reservoir induced. Accepted cases are those in which seismicity at the site had demonstrable temporal and/or spatial relationships to the reservoir impoundment or water level fluctuation history. "Not RIS" cases are those for which seismic activity was clearly established as unrelated to the reservoir impoundment. Questionable cases are those for which sufficient data were not available to discern the temporal and/or spatial relationsips of seismicity to the reservoir impoundment.

These criteria for RIS classification involve the spatial and temporal influence of the reservoir on the macroseismicity and the microseismicity of the reservoir local area. In the evaluation of each reported case of RIS, macroearthquake activity was considered independently of microearthquake activity. Macroseismic data generally were obtained from published catalogs of the International Seismological Centre (ISC) and the National Oceanographic and Atmospheric Administration (NOAA). Microseismic data were obtained from published results of local seismic networks.

For macroseismicity, the first criterion considered was the frequency of seismicity before and after reservoir impoundment: whether there was an increase, decrease, or no change in the seismicity within three to five radii of the center of the reservoir. The second criterion considered was the spatial relationship of post-impoundment seismicity to the reservoir: whether or not the post-impoundment seismicity was either beneath the reservoir or within the reservoir local area. The third criterion considered was the temporal relationship of the post-impoundment seismicity to water fluctuations: whether the local area seismicity occurred during or shortly after the initial impoundment or only after some delay and whether or not the occurrence of this seismicity may have been in response to water level fluctuations.

After applying these criteria to each reservoir, an evaluation was made as to whether or not sufficient macroseismic data were available to support the premise that the reservoir had influenced the macroseismicity of its immediate region. A similar procedure was used to evaluate available microseismic data. These procedures allowed a consistent classification of each reported case as accepted or questionable reservoir induced macroseismicity and/or microseismicity, or as seismic activity not affected by or related to the reservoir impoundment. Results of these evaluations are presented in Table 2-1.

Of the 64 reservoirs studied, 45 were concluded to be accepted cases of RIS. Of these 14 were concluded to be accepted macro RIS, 15 micro RIS, and 16 both macro and micro RIS. Seven reported cases were concluded to be not accepted RIS, and 12 cases were questionable. In the later stages of this study, limited information was obtained on an additional 13 reported cases of RIS, although data on some of these 13 were already included in the studied population of deep and/or very large reservoirs. These 13 reservoirs are: Idikki/Cheruthoni in India; Paraibuna/Paraitinga, Capivari, Capivara, Furnas, Salto Santiago, and Oros in Brazil; Lake Gordon in Australia; Lake Pukaki (a raised glacial lake) in New Zealand; Toktogol in USSR; and three reservoirs (names unknown) in China. No evaluations were made of these reported cases of RIS, and they are not listed in Table 1-1.

Application of the classification criteria to each reservoir was, at times, quite complicated. Because of location inaccuracies in the published catalogs, certain events that were shown occurring closer to the reservoir than they actually did might be identified as reservoir induced, and the converse could also occur. For many reservoirs, no information is available in the literature about the impoundment or fluctuation history. In these instances, the relationship between water level changes and post-impoundment seismicity could not be assessed. The systematic application of classification criteria minimized the inconsistencies that these complications tended to introduce.

# TABLE 2-1

# EVALUATION OF REPORTED CASES OF RESERVOIR INDUCED SEISMICITY

## MACROSEISMICITY

| Reservoir | Change in Seismicity Level[1] | | | Spatial Association w/ Reservoir[2] | Time of Seismicity | | Correlation with Water Level Changes | | | Influence on Macro[3] |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inc. | Dec. | N/C | | Initial Impoundment | Delay | Yes | No | Unclear | |
| Akosombo (Lake Volta) | | | X | Y | X | | | | | Y |
| Almendra | | | X | N | | | | | | N |
| Bajina Basta | | | X | Y | X | | | | | Y |
| Benmore | X | | | Y | X | | | | | Y |
| Blowering | X | | | Y | | X | | | X | Y |
| Cabin Creek | | | X | N | | | | | | N |
| Cajuru | | | X? | Y | | | | X | | U |
| Camarillas | | | X | Y | X | | | | | Y |
| Canelles | | | X | Y | X | | | | | Y |
| Clark Hill | | | X | Y | | X | | X | | U |
| Contra | | | X | | | | | | | N |
| Coyote Valley (Lake Mendocino) | | | X | Y | X | X | X | | | Y |
| El Grado | | | X | U | | | | | | N |
| Emosson | | | X | | | | | | | N |
| Eucumbene | X | | | Y | X | X | X | | | Y |
| Fairfield (Lake Monticello) | | | X | N | | | | | | N |
| Ghirni | | | X | | | | | | | N |
| Grancarevo | | | X | N | | | | | | N |
| Grandval | X | | | Y | | X | X | | | Y |
| Hendrik Verwoerd | | | X | N | | | | | | N |
| Hoover (Lake Mead) | X | | | Y | X | X | X | | | Y |
| Itezhitezhi | | | X | Y? | | X | | | | Y |
| Jocassee | | | X | Y | X | X | | X | | Y |
| Kamafusa | | | X | | | | | | | N |
| Kariba | X | | | Y | | X | Xweak | | | Y |
| Kastraki | X? | | | Y | X | X | | X | | Y |
| Keban | | | X | Y | | | | | | N |
| Kerr | X | | | Y | | X | | | | Y |
| Kinarsani | | | X | | | | | | | N |
| Koyna | X | | | Y | | X | X | | | Y |
| Kremasta | X? | | | Y | X | Y | | | X | Y |
| Kurobe | X | | | Y | X | X | X | | | Y |
| La Cohilla | | | | | | | | | | I |
| La Fuensanta | | | | | | | | | | I |
| Mangalam | | | N | | | | | | | N |
| Mangla | | | X | N | | | | | | N |
| Manicouagan 3 | X | | | Y | X | | | | | Y |
| Marathon | | | | Y | X | X | | X | | Yweak |
| Mica | | | X | U? | | | | | | N |
| Monteynard | | | | Y | X | X | | X | | Y |
| Mula | | | X | | | | | | | N |
| Nurek | | | X | | X | | | | | Y |
| Oroville | | | X | Yweak | | X | X | | | Y |
| Oued Fodda | | | X | | | | | | | N |
| Palisades | | | X | Y? | | X | | | X | U |
| Parambikulam | | | X | | | | | | | N |
| Piastra | | | X | Y | X | | | | | Y |
| Pieve de Cadore | X | | | U | X | | | | | Y |
| Porto Colombia | | | X | Y | X | | | | | Yweak |
| Rocky Reach | | | X | Y | | | | | | N |
| Sanford | | | X | N | | | | | | N |
| San Luis | | | X | N | | | | | | N |
| Schlegeis | | | X | | | | | | | N |
| Sefid Rud | | | X | Y | | X | | | X | U |
| Sharavathi | | | X | | | | | | | N |
| Shasta | | | X | | | | | | | N |
| Sholayar | | | X | | | | | | | N |
| Taibingo | X | | | Y | X | X | | | X | Y |
| Ukai | | | X | | | | | | | N |
| Vajont | | | X | ? | | | | | | N |
| Volta Grande | | | X | Y | X | | | | | Yweak |
| Vouglans | X | | | Yweak | | X | X | | | Y |
| Warragamba | X | | | Y | | X | | | | U? |
| Xinfengjiang | X | | | Y | | X | X | | | Y |

Notes:

1. Inc. = Increase; Dec. = Decrease; N/C = No Change
2. Y = Yes; N = No; U = Unclear
3. Y = Yes; N = No; U = Unclear; I = Insufficient Data to Evaluate

# TABLE 2-1

# EVALUATION OF REPORTED CASES OF RESERVOIR INDUCED SEISMICITY

## MICROSEISMICITY

| Reservoir | Pre-Impoundment Monitoring | Post-Impoundment Monitoring | Change in Seismicity Level[1] | | | Spatial Association with Reservoir[2] | Timing of Seismicity | | Correlation with Water Level Changes | | | Influence on Micro[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Inc. | Dec. | N/C | | Initial Impoundment | Delay | Yes | No | Uncertain | |
| Akosombo (Lake Volta) | | | | | | | | | | | | I |
| Almendra | | X | | | | Y | X | X | | | X | Y |
| Bajina Basta | | | | | | | | | | | | I |
| Benmore | | X | | | | Y | X | X | | | X | Y |
| Blowering | | X | | | | Y | | X | | | X | Y |
| Cabin Creek | | X | | | | N | | | | | | N |
| Cajuru | | | | | | | | | | | | I |
| Camarillas | | | | | | | | | | | | I |
| Canelles | | | | | | | | | | | | I |
| Clark Hill | | X | | | | Y | | X | X | | | Y |
| Contra | | X | | | | Y | X | X | | | X | Y |
| Coyote Valley (Lake Mendocino) | | | | | | | | | | | | I |
| El Grado | | | | | | | | | | | | I |
| Emosson | X | X | | | | Y | X | X | X | | | Y |
| Eucumbene | | | | | | | | | | | | I |
| Fairfield (Lake Monticello) | | X | | X? | | N | X | X? | | | X | Y |
| Ghirni | | | | | | | | | | | | I |
| Grancarevo | | X | | X | | Y | X | X | X | | | Y |
| Grandval | | X | | X | | Y? | X | | | | | Y |
| Hendrik Verwoerd | X | X | X | | | Y | X | ? | ? | | | Y |
| Hoover (Lake Mead) | | X | | | | Y | X | X | X | | | Y |
| Itzhitezhi | | | | | | | | | | | | I |
| Jocassee | | X | | | | Y | | X | | X | | Y |
| Kamafusa | X | X | X | | | Y | | | | | | Y |
| Kariba | | X | | | | Y | | X | X | | | Y |
| Kastraki | X | X | | | | Y | X | X | | X | | Y |
| Keban | | X | | | | Y | X | | | | | Y |
| Kerr | | | | | | | | | | | | I |
| Kinarsani | | | | | | | | | | | | I |
| Koyna | | X | | | | Y | X | X | X | | | Y |
| Kremasta | X | X | | | | Y | X | X | | | X | Y |
| Kurobe | | X | | | | Y | X | X | X | | | Y |
| La Cohilla | | | | | | | | | | | | I |
| La Fuensanta | | | | | | | | | | | | I |
| Mangalam | | | | | | | | | | | | I |
| Mangla | | X | | | X | U | | | | | | N |
| Manicouagan 3 | | X | | | | Y | X | X | | X | | Y |
| Marathon | | | | | | | | | | | | I |
| Mica | X | X | | | X | | | | | | | N |
| Monteynard | | | | | | | | | | | | I |
| Mula | | X | X | | | Y | X | | | | | Y |
| Nurek | | X | X | | | Y | X | X | X | | | Y |
| Oroville | | | | | ? | | | | | | | I |
| Oued Fodda | | X | | | | Y | X | | | | | Y |
| Palisades | | X | | | | | | X | X | | | Yweak |
| Parambikulam | | | | | | | | | | | | I |
| Piastra | | X | | | | | X | | | | | Y |
| Pieve de Cadore | | X | | | | Y | X? | X | X | | | Y |
| Porto Colombia | | | | | | | | | | | | I |
| Rocky Reach | X | X | | | X | Y | | | | | | N |
| Sanford | | | | | | | | | | | | I |
| San Luis | | | | | | | | | | | | N |
| Schlegeis | | X | | | | Y | | X | X | | | Y |
| Sefid Rud | | X | | | | U | X | X | | | X | U |
| Sharavathi | | | | | | | | | | | | I |
| Shasta | | | X | | | ? | X | | | | | Yweak |
| Sholayar | | | | | | | | | | | | I |
| Talbingo | X | X | | | | Y | X | X | X | | | Y |
| Ukai | | | | | | | | | | | | I |
| Vajont | | X | | | | Y | X | X | X | | | Y |
| Volta Grande | | | | | | | | | | | | I |
| Vouglans | | | | | | | | | | | | I |
| Warragamba | | | | | | | | | | | | I |
| Xinfengjiang | | X | | | | Y | X | X | ? | | | Y |

Notes:

1. Inc. = Increase; Dec. = Decrease; N/C = No Change
2. Y = Yes; N = No; U = Unclear
3. Y = Yes; N = No; U = Unclear; I = Insufficient Data to Evaluate

Although a relatively consistent seismic data base could be established from worldwide catalogs for macroearthquakes, no such consistency exists in the literature on the recording and reporting of microseismic events occuring near or under a reservoir. Therefore, a consistent data base on microearthquakes was not possible. For a few reservoirs, post-impoundment microseismicity is well documented from high-gain seismic networks placed around the reservoir. In these cases, it was usually possible to assess the proximity of post-impoundment seismicity to the reservoir, although locations are not always provided in the literature. Similarly, where detailed microseismic data and water level histories are available, the relationship between water level fluctuations and the occurrence of local earthquakes could be assessed.

These complications probably explain why systematic reviews of the reported cases of RIS have not often been attempted (exceptions include Packer and others, 1977; Simpson, 1976). The classification undertaken in this study required many judgmental decisions as to the quality and implications of data.

The strongest association between a reservoir and seismicity is inferred when local post-impoundment seismic activity rises and falls in direct association with changes in water level. A strong association also is inferred when the initial impoundment of a reservoir is accompanied or quickly followed by an increase in seismic activity in the reservoir local area; the association is particularly strong if this occurs in an area previously considered to be seismically quiescent on the basis of the historical record. Conversely, when the post-impoundment seismicity occurs some time after the initial impoundment but exhibits no clear relationship to water level fluctuations, or when the spatial association of post-impoundment seismicity to the reservoir is ambiguous, the case for RIS is considered to be weak.

The criteria adopted for this study do not distinguish between coincidental association of reservoirs and seismicity and the actual triggering of earthquakes by impoundment of a reservoir. However, the emphasis on temporal and spatial associations helps to minimize this problem. No specific tests were performed to evaluate the randomness of recognized associations. Accordingly, it was assumed that a case of RIS would be accepted if the seismicity was within the criteria defined for reservoir influence.

In the following section, four reservoirs or pairs of reservoirs having reported RIS are provided as examples to illustrate the evaluation procedure. These four examples were chosen because they reflect different levels of quality in the data, different kinds of RIS (macro versus micro), and different levels of confidence in the assessment of the influence of the reservoir on post-impoundment seismicity.

### 2.3.2 Four Selected Cases of Reported RIS

Kremasta/Kastraki - Kremasta reservoir and Kastraki reservoir (downstream from Kremasta) are located in southern Greece on the Acheloos River (Figure 1-1). Kremasta reservoir began filling in July 1965, and Kastraki reservoir in January 1969 (see Appendix A). A plot of the historical macroseismicity of the area for the years 1912 to 1975 (Figure 2-1) indicates that the Kremasta/Kastraki area is one of moderate pre-impoundment and high post-impoundment seismic activity. Pre-impoundment macroseismicity in the Kremasta/Kastraki region generally was located outside of the reservoir local area. Although seismograph coverage in the area was poor prior to mid-1965, most larger events ($M \geq 4.5$) were recorded

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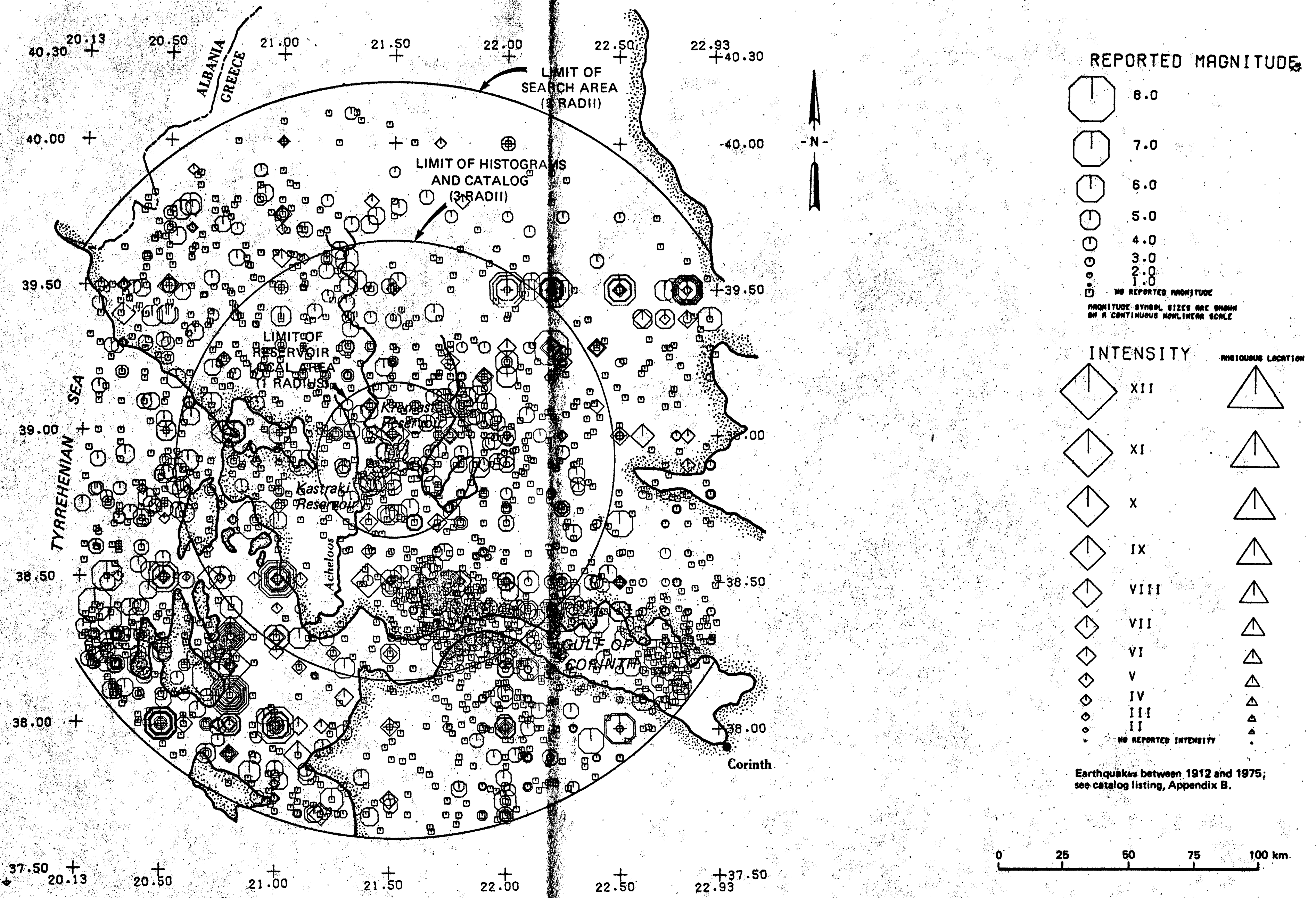


Earthquakes between 1912 and 1975; see catalog listing, Appendix B.

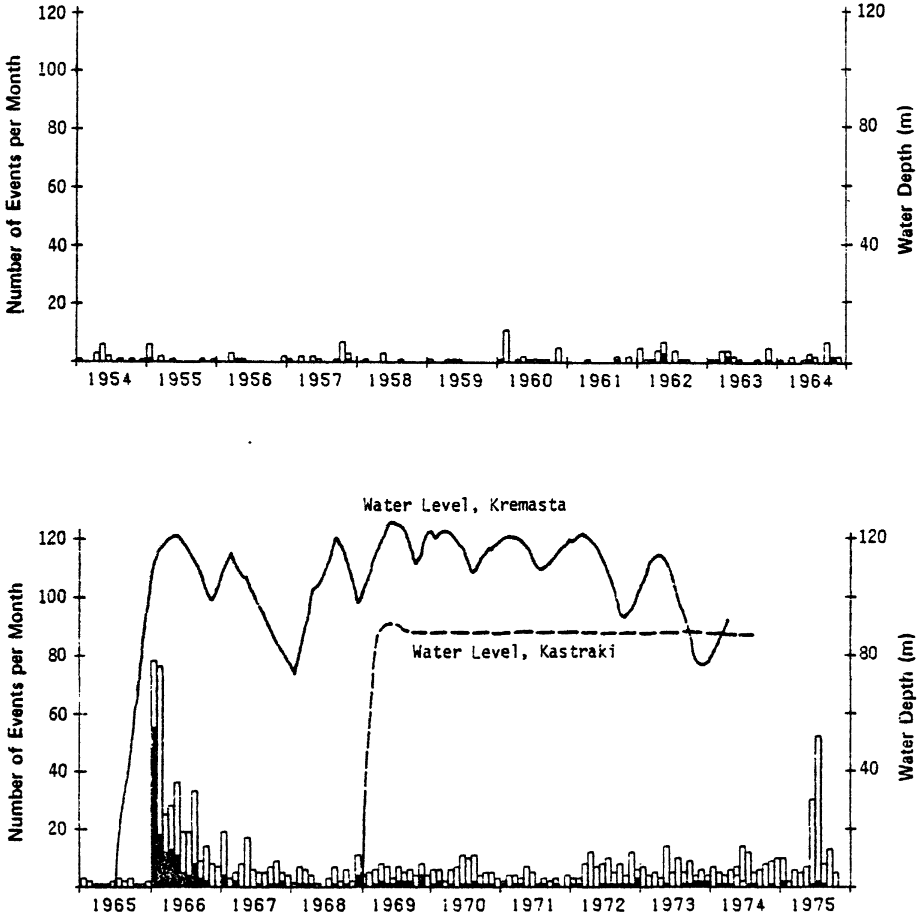
**HISTORICAL MACROSEISMICITY**
**VICINITY OF KREMASTA-KASTRAKI**
Greece

| | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 2-1<br>Page 25 |

regional networks. Evaluations of felt reports near the dam sites indicate sparse local macroseismic activity prior to 1965 (Drakopoulos, 1974; Comninakis and others, 1969).

In August 1965, as part of an increased coverage by the Greek seismic network, a seismograph station was established on Kephallenia island, about 115 km from the Kremasta Dam (Comninakis and others, 1969). This station provided additional data on post-impoundment seismicity near Kremasta/Kastraki. Figure 2-2 illustrates the marked rise in macroseismic activity in early 1966 near Kremasta; many of these events occurred under the reservoir and were felt at the dam. This activity culminated in a main shock, $M_L$ 6.3, on 5 February 1966 (Comninakis and others, 1966). Following the aftershock sequence of this event, seismicity decreased to a level higher than pre-impoundment activity. Although it can be argued that the apparent increased level of seismicity reflects increased seismograph coverage rather than an actual increase in seismicity, the record of felt reports for the Kremasta/Kastraki area strongly indicates that macroseismicity for several years after impoundment was significantly more frequent than macroseismicity for the years prior to impoundment of Kremasta reservoir (Therianos, 1974; Drakopoulos, 1974).

Following the early 1969 impoundment of Kastraki reservoir, an increase in local macroearthquake activity was reported (Drakopoulos, 1974; Bozovic, 1974); however, this increase was less pronounced than that at Kremasta and is not clearly illustrated on ISC records (Appendix B; Figure 2-2). These post-impoundment events in the Kremasta/Kastraki area were adjacent to or under the reservoirs, whereas pre-impoundment seismicity was not located in the immediate vicinity of the reservoirs. The post-impoundment macroseismic activity is strongly spatially correlated with the reservoirs, and



EXPLANATION:

① Number of earthquakes within three radii of center of reservoir

② Number of earthquakes between one and three radii of center of reservoir

③ Number of earthquakes within one radius of center of reservoir

——— Actual water level

– – – Assumed water level

Note: Radius of 28.0 km for Kremasta reservoir

Source: Water level histories from Bozovic (1974)

HISTOGRAM OF EARTHQUAKES
AND WATER LEVEL HISTORIES
VICINITY OF KREMASTA-KASTRAKI
Greece

| | |
|---|---|
| Project No. 14087A | Figure 2-2 |
| **Woodward-Clyde Consultants** | Page 27 |

particularly strongly related to initial impoundment. Subsequent post-impoundment macroseismic activity was not clearly correlated with changes in water level.

The Kephallenia seismograph station detected post-impoundment earthquakes in the Kremasta/Kastraki area with magnitudes as low as $M_L$ 2. The first small-magnitude local earthquakes at the Kremasta Dam were reported in August 1965, during initial impoundment. Larger earthquake swarms were recorded in December 1965 and January 1966, before the main shock on 24 January 1966 (Comninakis and others, 1969). The microearthquake activity is spatially correlated with the reservoir and with initial impoundment. Subsequent microseismic activity was not clearly correlated with changes in water level. Because of the clear influence of reservoir impoundment on both macroseismicity and microseismicity at Kremasta/Kastraki, this reservoir system is classified as an accepted case of RIS at both the macro and the micro levels.

Porto Colombia/Volta Grande - Porto Colombia and Volta Grande reservoirs are located in Minas Gerais, Brazil, on the Grande River, approximately 400 km northwest of Sao Paulo (Figure 1-1). The region around these reservoirs is characterized by extremely low historical seismicity (Figure 2-3 and Appendix B). On 24 February 1974, subsequent to impoundment of Porto Colombia and during impoundment of Volta Grande, an earthquake occurred in the area around the reservoirs (Figure 2-4). Local reports placed the probable epicenter under or adjacent to the Porto Colombia reservoir (Brito, 1974). No other information on post-impoundment seismicity has been obtained. Although the general level of seismicity in the area remained extremely low subsequent to impoundment, the timing and location of the 24 February 1974 earthquake suggests inducement by reservoir impoundment. This event is considered a weak but accepted case of macro RIS.

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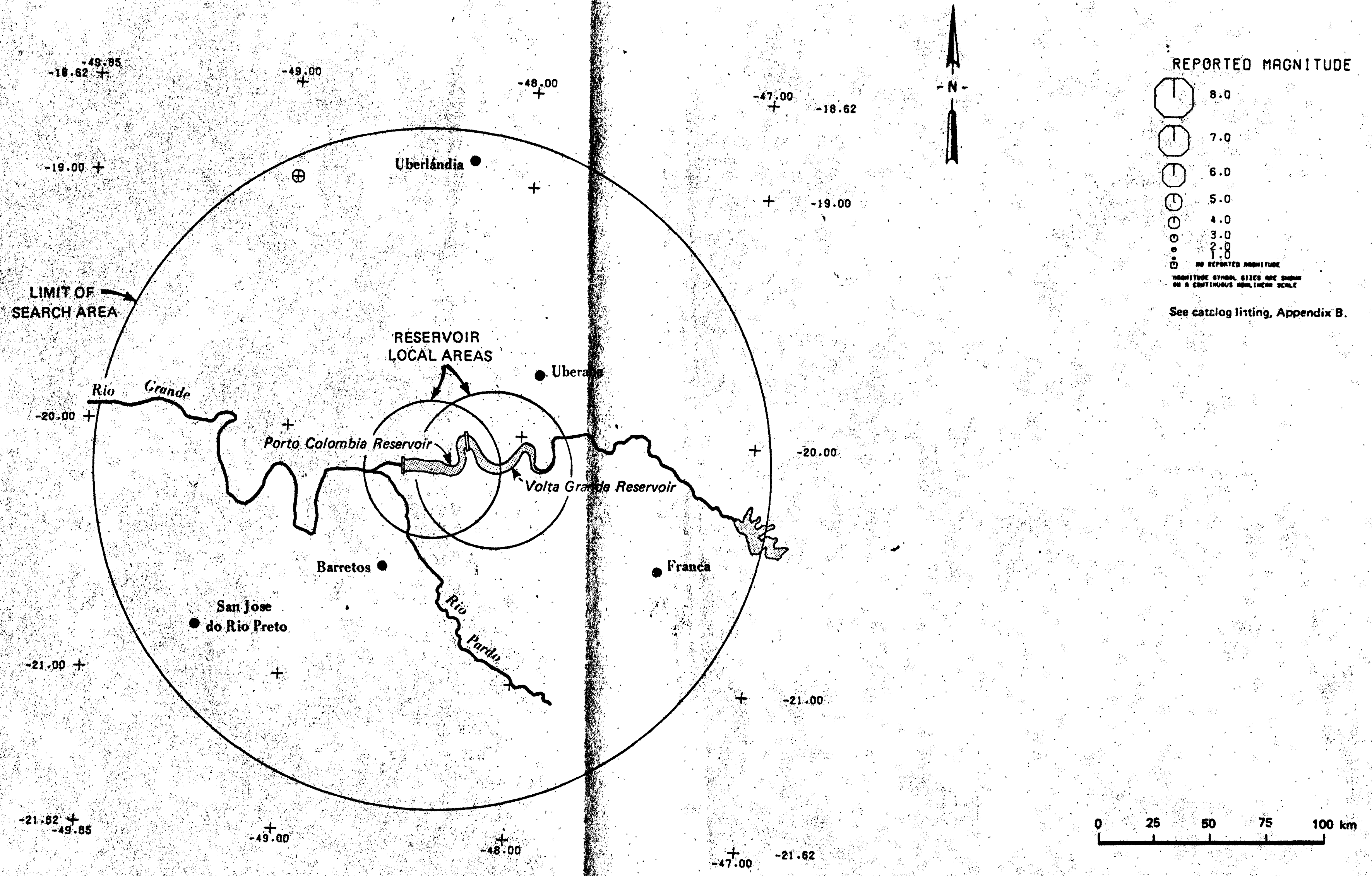

See catalog listing, Appendix B.

HISTORICAL MACROSEISMICITY
VICINITY OF PORTO COLOMBIA-
VOLTA GRANDE RESERVOIRS
Brazil

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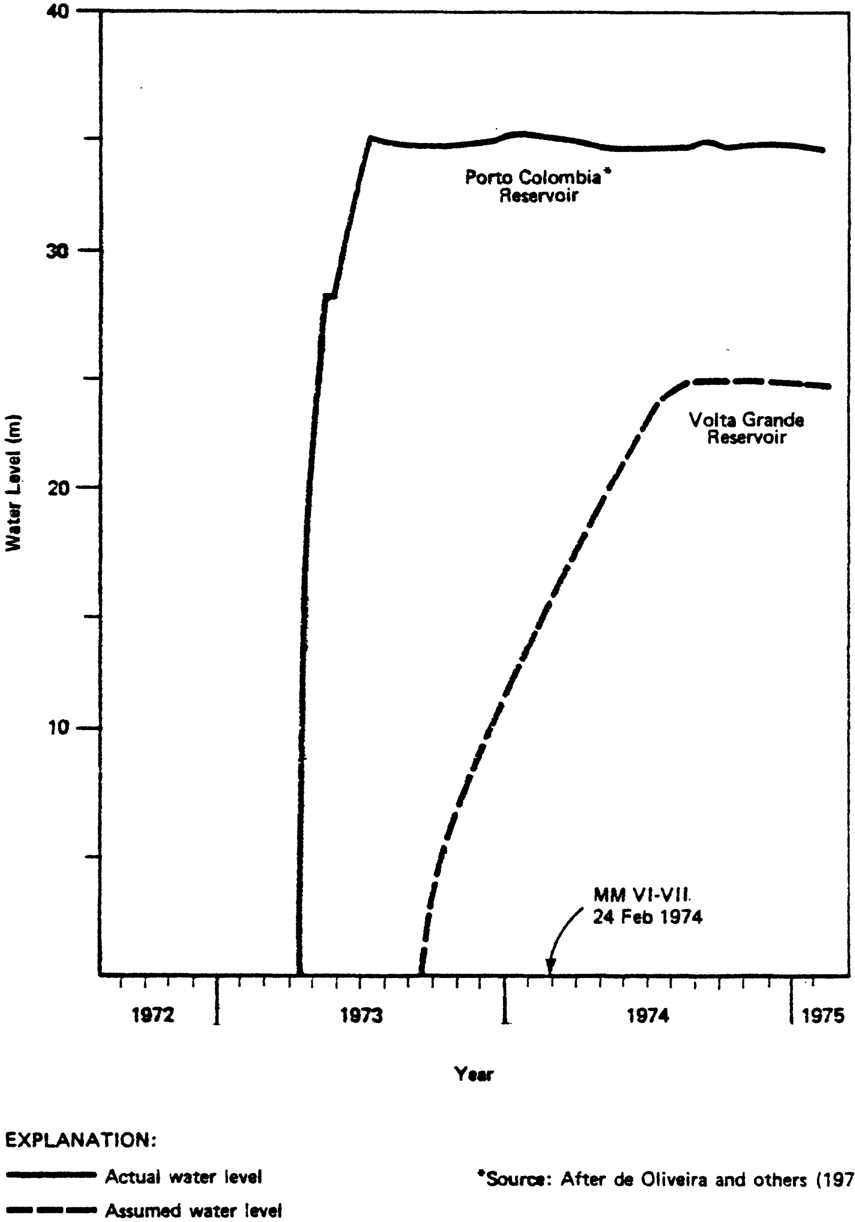
Figure 2-3



*Source: After de Oliveira and others (1976)

FILLING HISTORIES AND
REPORTED EARTHQUAKE
PORTO COLOMBIA-VOLTA GRANDE RESERVOIRS
Brazil

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 2-4

Almendra - Almendra (or Tormes) reservoir is located in western Spain near the Portuguese border (Figure 1-1), an area characterized by low historical seismicity (Figure 2-5 and Appendix B). A plot of macroseismic activity shows no change subsequent to impoundment (Figure 2-6). Post-impoundment macroseismicity is not spatially associated with the reservoir (Appendix B). Thus, the Almendra reservoir has had no influence on macroseismic activity in the area. Recent data on microseismic activity (Buforn and Udias, 1978) indicate a strong relationship between the impoundment of Almendra and microearthquake activity (Figure 2-7). Seismic monitoring of the area around Almendra between November 1971 and July 1972 indicated that microearthquake activity paralleled reservoir impoundment (Buforn and Udias, 1978). During rapid filling early in 1972, microearthquake activity increased, reaching a peak 45 days after the water level peaked (Figure 2-7). As the reservoir water level decreased, microseismic activity also lessened. All events were within 25 km of the dam; most were adjacent to or under the reservoir and had very shallow focal depths.

Although the period of microearthquake monitoring is limited, the study by Buforn and Udias (1978) indicates a strong correlation between the impoundment of the Almendra (Tormes) reservoir and microearthquake activity. Thus, Almendra is classified as an accepted case of micro RIS.

Sefid Rud - The Sefid Rud reservoir is located in northern Iran, 220 km west-northwest of Tehran (Figure 1-1). The region has moderate historical macroseismicity; regionally destructive earthquakes have occurred in 1119, 1167, 1639, and 1808 (Tchalenko and others, 1974). Since 1944, seismic events have occurred in scattered locations throughout the reservoir region (Figure 2-8).

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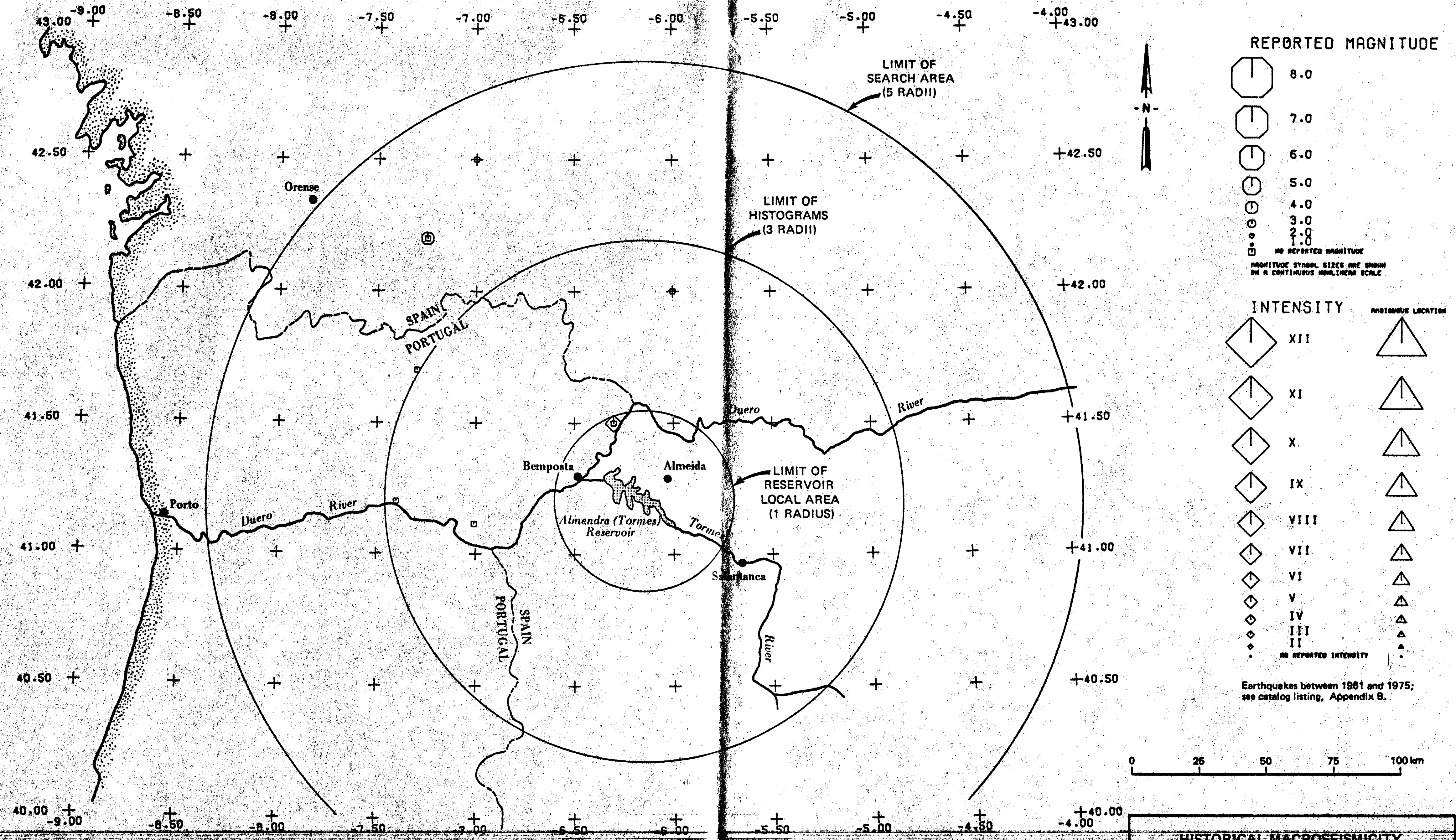
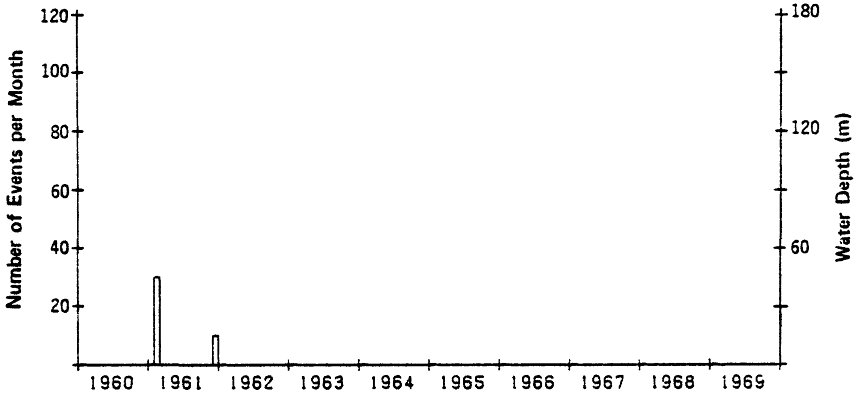


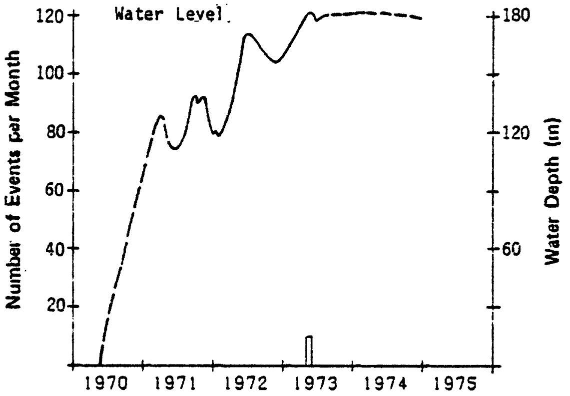
Earthquakes between 1961 and 1975; see catalog listing, Appendix B.

HISTORICAL MACROSEISMICITY
VICINITY OF ALMENDRA
Spain

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 2-5





EXPLANATION:

▯ } ② } ① ① Number of earthquakes within three radii of center of reservoir

② Number of earthquakes between one and three radii of center of reservoir

▮ } ③ ③ Number of earthquakes within one radius of center of reservoir

——— Actual water level

– – – – Assumed water level

Note: Radius of 32.5 km for Almendra (Tormes) reservoir

Source: Filling history modified from Buforn and Udias (1978)

## HISTOGRAM OF EARTHQUAKES AND FILLING HISTORY VICINITY OF ALMENDRA
Spain

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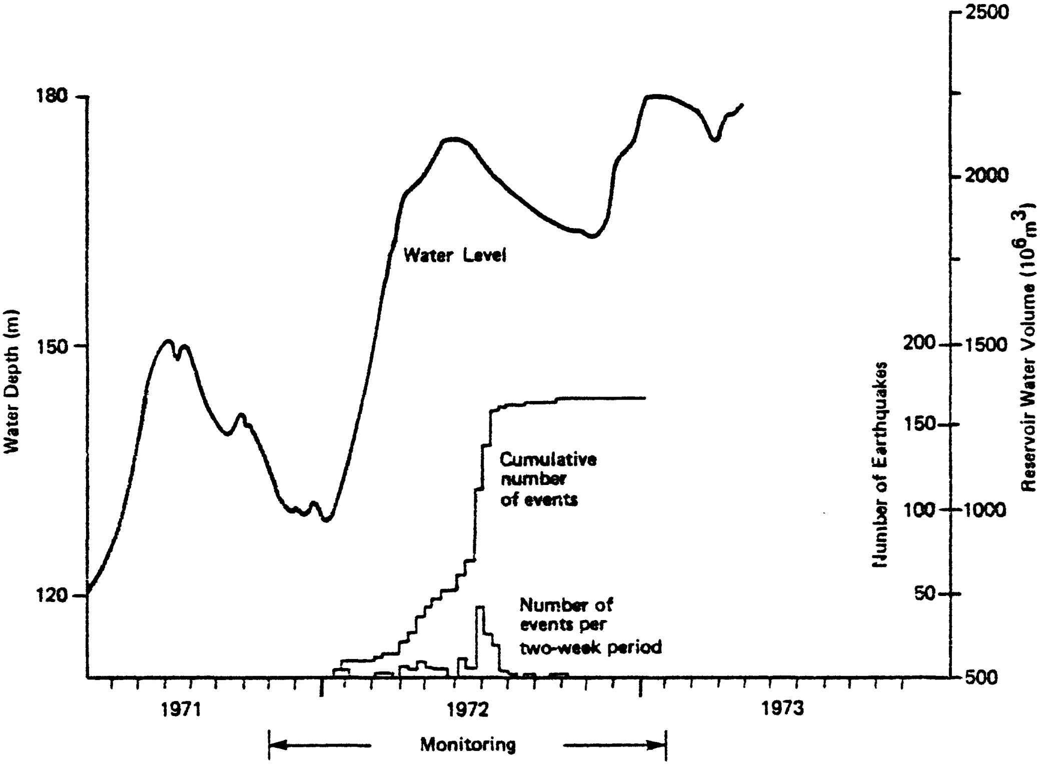
**Woodward-Clyde Consultants**

Figure 2-6



Source: Buforn and Udias (1978)

| LOCAL SEISMICITY DURING IMPOUNDMENT<br>ALMENDRA<br>Spain | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 2-7<br>Page 34 |

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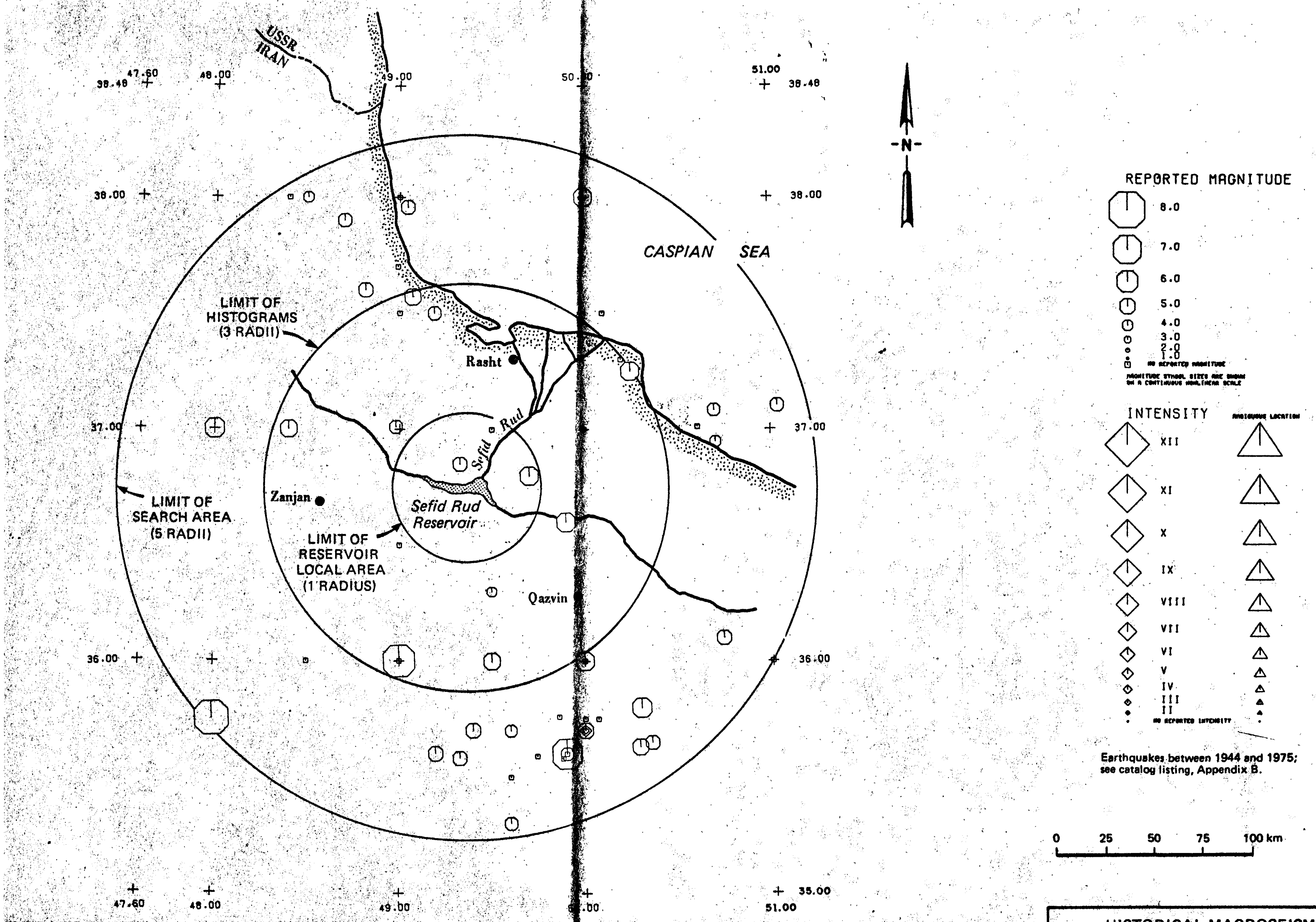

Earthquakes between 1944 and 1975;
see catalog listing, Appendix B.

HISTORICAL MACROSEISMICITY
VICINITY OF SEFID RUD
Iran

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 2-8
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A comparison of the levels of macroseismicity before and after impoundment indicates no significant change (Figure 2-9). Macroseismic events that occurred in 1962 during impoundment were mainly located more than 50 km from the reservoir (Appendix B); the single closest event was a possible aftershock of a M 7.5 event that was located more than 80 km from the reservoir. The Sefid Rud reservoir, therefore, is considered to have had no influence on macroseismicity during its initial impoundment.

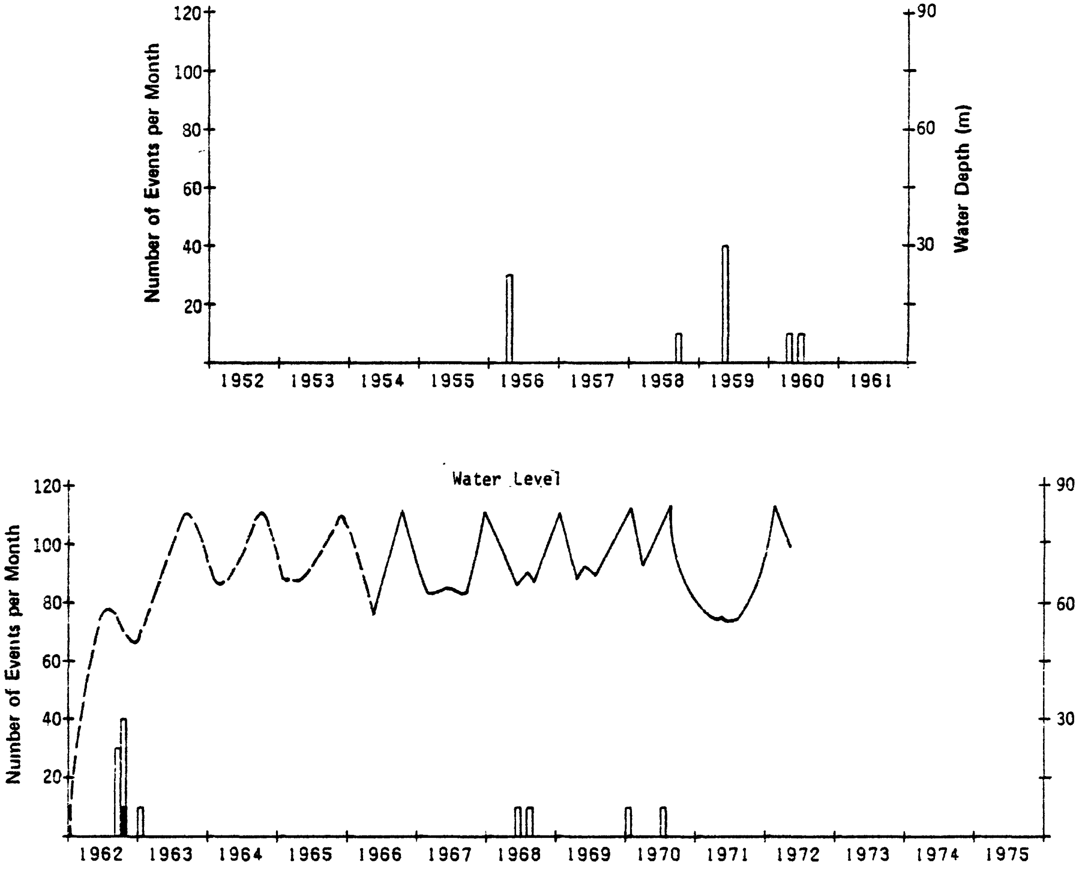
In 1968, several years after impoundment, a M 4.7 earthquake, having a focal depth of 36 km, was recorded near the reservoir (Figure 2-10 and Appendix B). However, no clear correlation has been observed between this event and fluctuations in the water level of the reservoir. Thus, Sefid Rud is considered a questionable case of macro RIS.

Massoud-Peyman (undated) discusses post-impoundment microseismicity at Sefid Rud. A seismograph station installed at the dam recorded an average of 120 low magnitude earthquakes per year within 100 km of the dam; however, locations for these events are not provided and therefore assessment of the spatial association of these events with reservoir impoundment is difficult. Furthermore, no clear correlation is observed between local earthquakes and water level changes (Figure 2-10). Therefore, because of the ambiguities in the data, Sefid Rud is considered a questionable case of micro RIS.

## 2.4 STATISTICAL ANALYSIS

### 2.4.1 Parameters Used for Statistical Analysis

From all the data compiled on all deep and/or very large reservoirs, five parameters were chosen for statistical



EXPLANATION:

① Number of earthquakes within three radii of center of reservoir
② Number of earthquakes between one and three radii of center of reservoir
③ Number of earthquakes within one radii of center of reservoir

——— Actual water level
– – – – Assumed water level

Note: Radius of 35 km for Sefid Rud reservoir

Source: Water level history modified from Massoud-Peyman (undated)

HISTOGRAM OF EARTHQUAKES
AND WATER LEVEL HISTORY
VICINITY OF SEFID RUD
Iran

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 2-9
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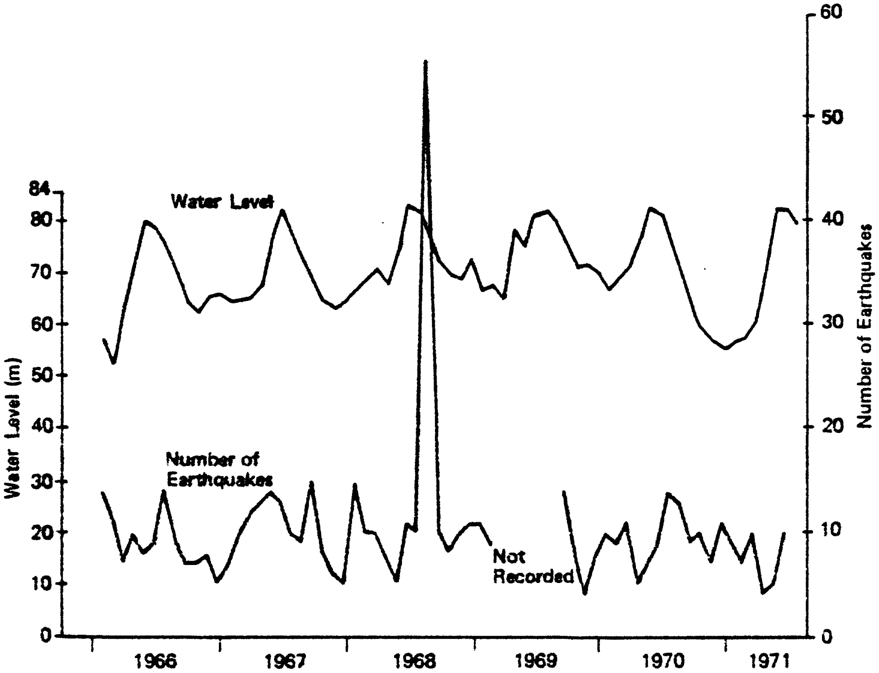


Source: After Massoud-Peyman (undated)

LOCAL EARTHQUAKES (1966-1971)
AND WATER LEVEL FLUCTUATIONS
SEFID RUD
Iran

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 2-10

analysis: maximum water depth, maximum water volume, type of regional stress, fault activity, and type of geology. These parameters were chosen because they may be significant factors in assessing the probability of reservoir induced seismicity and because abundant information on them was available (fault activity is an exception). Information on each of these parameters was gathered as described in the preceding sections: water depth was obtained from reports or was estimated; water volume was obtained from dam listings; regional stress regime was assessed either from focal mechanisms, faulting sense, or tectonics; and fault activity and geology were obtained from the literature. For statistical purposes, the geology of a reservoir local area was classified as sedimentary, igneous, or metamorphic, depending on the prevalent rock type.

### 2.4.2 Method of Study for Statistical Analysis

The five parameters utilized in the statistical analysis are termed statistical attributes of the reservoir. These attributes are denoted D, V, S, F, and G for depth, volume, stress regime, presence of active faulting, and geology, respectively. Attributes can have different states; for example, the depth attribute can have the states shallow, deep, or very deep. Therefore, state descriptions for each attribute are denoted by a lower case letter and subscript numeral (see Table 2-2). As an example, for depth D, state $d_1$ means very deep, state $d_2$ means deep, and state $d_3$ means shallow. Furthermore, reservoirs were categorized into those with accepted induced seismicity (accepted RIS) and those with not-accepted RIS (including no report of RIS, not RIS, and questionable RIS).

The data were first examined to obtain relationships between single attribute states and the occurrence of RIS. Two data

TABLE 2-2: NOTATION FOR RESERVOIR ATTRIBUTES, STATISTICAL ANALYSIS.

| | State Description | | | |
|---|---|---|---|---|
| Attribute | 1 | 2 | 3 | 4 |
| DEPTH (D) | $d_1$ = very deep (over 150 m) | $d_2$ = deep (92 to 150 m) | $d_3$ = shallow (less than 92 m) | $d_4$ = (not known) |
| VOLUME (V) | $v_1$ = very large (over $10^{10}$ $m^3$) | $v_2$ = large [12 to 100 (x $10^8$)$m^3$] | $v_3$ = small [less than 12(x$10^8$)$m^3$] | $v_4$ = (not known) |
| STRESS STATE (S) | $s_1$ = extensional | $s_2$ = compressional | $s_3$ = shear | $s_4$ = (not known) |
| FAULT ACTIVITY (F) | $f_1$ = active fault present | $f_2$ = no active faults present | $f_3$ = (not known) | |
| GEOLOGY (G) | $g_1$ = sedimentary | $g_2$ = metamorphic | $g_3$ = igneous | $g_4$ = (not known) |

sets were used: 1) the set of reservoirs that are deep, very deep (maximum water depth greater than 150 m), and/or very large; and 2) the set of reservoirs that are deep or very deep. The first set contained 29 instances of accepted RIS and 205 instances of not-accepted RIS; the second set contained 28 instances of accepted RIS and 172 instances of not-accepted RIS. The number of occurrences of different states of each attribute are shown in Table 2-3 (A and B) for these two data sets. Numbers in parentheses indicate relative frequency of a particular attribute state. For instance, in the first data set, 10 of the 29 reservoirs with accepted RIS are categorized as very deep (state $d_1$). Therefore, the frequency of very deep reservoirs among reservoirs having accepted RIS is 10/29 or 0.34. In most of the subsequent analyses, most attention was directed at the second data set, containing only deep and very deep reservoirs.

For the first data set of reservoirs (deep, very deep, and/or very large), the frequency ("prior probability") of RIS, given no specific knowledge of the reservoir itself, is 0.12. Prior probability is the number of accepted RIS cases (29) divided by the total number of deep, very deep, and/or very large reservoirs, which is 234. The prior probability of not-accepted RIS at such a reservoir is the complement of 0.12, or 0.88. For the second data set (deep and very deep reservoirs), the frequencies are 0.14 for RIS and 0.86 for not-accepted RIS.

For each attribute taken individually, a particular attribute state can be considered either not to occur or to occur. This corresponds to the Bernoulli model of probabilistic trials. The probability of "success" (i.e., the occurrence of a particular attribute state) is "p", and the probability of "failure" (i.e., that attribute state does not occur) is "1 - p". Because of statistical fluctuation in data,

TABLE 2-3 (A): LIKELIHOODS OF ATTRIBUTE STATES FOR ACCEPTED RIS AND NOT-ACCEPTED RIS, BASED ON DEEP, VERY DEEP, AND/OR VERY LARGE RESERVOIR DATA.

| | Number of Reservoirs | State | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Accepted RIS[a] | | | | |
| Depth | 29 | 10 (0.34) | 18 (0.62) | 1 (0.03) |
| Volume | 29 | 7 (0.24) | 11 (0.38) | 11 (0.38) |
| Stress State | 29 | 4 (0.14) | 18 (0.62) | 7 (0.24) |
| Fault Activity | 7 | 7 (1.00) | 0 (0.00) | |
| Geology | 28 | 13 (0.46) | 8 (0.29) | 7 (0.25) |
| Not-Accepted RIS[a] | | | | |
| Depth | 204 | 27 (0.13) | 144 (0.71) | 33 (0.16) |
| Volume | 205 | 52 (0.25) | 36 (0.18) | 117 (0.57) |
| Stress State | 203 | 34 (0.17) | 138 (0.68) | 31 (0.15) |
| Fault Activity | 6 | 4 (0.67) | 2 (0.33) | |
| Geology | 165 | 57 (0.35) | 64 (0.39) | 44 (0.26) |

---

[a] The conditional probability of a state is shown in parentheses.

TABLE 2-3 (B) LIKELIHOODS OF ATTRIBUTE STATES FOR ACCEPTED RIS AND NOT-ACCEPTED RIS, BASED ON DEEP AND VERY DEEP RESERVOIR DATA.

| | | State | | |
|---|---|---|---|---|
| | Number of Reservoirs | 1 | 2 | 3 |
| Accepted RIS[a] | | | | |
| Depth | 28 | 10 (0.36) | 18 (0.64) | 0 |
| Volume | 28 | 6 (0.22) | 11 (0.39) | 11 (0.39) |
| Stress State | 28 | 4 (0.14) | 18 (0.64) | 6 (0.22) |
| Fault Activity | 6 | 6 (1.00) | 0 (0.00) | |
| Geology | 27 | 13 (0.48) | 8 (0.30) | 6 (0.22) |
| Not-Accepted RIS[a] | | | | |
| Depth | 171 | 27 (0.16) | 144 (0.84) | 0 |
| Volume | 171 | 18 (0.11) | 36 (0.21) | 117 (0.68) |
| Stress State | 171 | 33 (0.19) | 109 (0.64) | 29 (0.17) |
| Fault Activity | 6 | 4 (0.67) | 2 (0.33) | |
| Geology | 143 | 44 (0.31) | 60 (0.42) | 39 (0.27) |

---

[a] The conditional probability of a state is shown in parentheses.

estimates of the parameter, p, may vary from one data set to the next. To calculate the sampling variance, V, in estimates of p, the equation p(1 - p)/n, where n is the number of data in the set, is used. (This equation is based on the model of independent trials.) Thus, for example, because 10 of the 29 reservoirs with accepted RIS are very deep, the best estimate of probability (denoted p) is 0.34, and consequently, the best estimate of $1 - \hat{p}$ is 0.66. Since n is 29, the variance associated with this estimate of p is

$$V\ [\hat{p}] = \frac{(0.34)(0.66)}{29} = 0.0077$$

The standard deviation, which is the square root of the variance, is 0.088.

Sampling variances for all the parameters of Table 2-3 are shown in Table 2-4. Because the present analysis is based on techniques of classical estimation, empty data cells yield estimates where $\hat{p}$ equals zero. For example, for those seven accepted RIS cases having data on fault activity, all seven were "active" ($f_1$). Therefore, $\hat{p}(f_2|\text{RIS}) = 0$, and $V[\hat{p}] = 0$. This is an aberation of the statistical techniques used; conclusions must be carefully drawn because of the small sample size.

To interpret Table 2-4, the RIS cases for very deep reservoirs can again be used as an example. The best estimate of the frequency of occurrence of the very deep RIS reservoirs is 0.34, with a variance of $7.8 \times 10^{-3}$; the standard deviation associated with that estimate is 0.088. This means that if 34 percent of all very deep reservoirs induce seismicity, then the frequency in the sample would also be expected to be 34 percent, but with a possible standard deviation of 0.088. More generally, if data were available on a very large number

TABLE 2-4: SAMPLING VARIANCE OF ATTRIBUTE LIKELIHOODS.[a]

| | State | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| RIS Data (x $10^{-3}$) | | | |
| Depth | 7.8 (8.2) | 8.1 (8.2) | 1.0 |
| Volume | 6.3 (5.9) | 8.1 (8.5) | 8.1 (8.5) |
| Stress State | 4.2 (4.3) | 8.1 (8.2) | 6.3 (6.1) |
| Fault Activity | -- | -- | |
| Geology | 8.9 (9.2) | 7.4 (7.8) | 6.7 (6.4) |
| Not-Accepted RIS Data (x $10^{-3}$) | | | |
| Depth | 0.56 (0.78) | 1.0 (0.78) | 0.66 |
| Volume | 0.92 (0.55) | 0.72 (0.97) | 1.2 (1.3) |
| Stress State | 0.70 (0.90) | 1.1 (1.3) | 0.63 (0.85) |
| Fault Activity | 37.0 (37.0) | 37.0 (37.0) | -- |
| Geology | 1.4 (1.5) | 1.4 (1.7) | 1.2 (1.4) |

---

[a] Numbers in parentheses refer to the data set on deep and very deep reservoirs. Numbers not in parentheses refer to the deep, very deep, and/or very large reservoir data set.

of reservoirs, the frequency of very deep reservoirs among the RIS set would be between 0.34 minus one standard deviation and 0.34 plus one standard deviation (or from 0.25 to 0.43) with a probability of approximately 85 percent. (For large sample sizes, the sampling distribution of $\hat{p}$ approaches Normality, and therefore, probabilities can be taken from tables of the Normal distribution.) A comparison of the variances of the accepted RIS with the not-accepted RIS cases in Table 2-4 shows that the variances of the not-accepted RIS cases are uniformly smaller. The reason for this is the much larger not-accepted RIS sample size.

### 2.4.3 Correlations Among Attributes

Statistical procedures were used to test whether apparent correlations among attributes were significant. In particular, correlations were examined for the six possible pairs of the four attributes (excluding faulting) which had sufficient data for significant tests. Because the correlations are based on the site being accepted RIS or not-accepted RIS, a total of 12 sets of data were used.

Table 2-5 is an illustration of the procedure used to examine correlation between attributes. For this example, the conditional probabilities of depth (D) and volume (V) for RIS cases for deep and very deep reservoirs are considered. (The term "conditional" will be taken as implicit when discussing probabilities unless otherwise noted; a conditional probability is the probability given the frequency of occurrence of a particular attribute state.) Because data are not available on all shallow reservoirs, this examination only considers the 28 deep and very deep accepted RIS cases (18 are deep and 10 are very deep). Consequently, the probability of a deep reservoir with accepted RIS is 18/28, and the probability of a very deep reservoir is 10/28. Similarly, for

TABLE 2-5: ILLUSTRATIVE TEST OF INDEPENDENCE BETWEEN TWO ATTRIBUTES, USING A CONTINGENCY TABLE, RIS DATA.

|  | Volume |  |  |  |
|---|---|---|---|---|
| Depth | $v_3$ | $v_2$ | $v_1$ | $n_i$ |
| $d_1$ | 4 (3.93) | 3 (3.93) | 3 (2.14) | 10 |
| $d_2$ | 7 (7.07) | 8 (7.07) | 3 (3.86) | 18 |
| $n_j$ | 11 | 11 | 6 | N=28 |

NOTE: Numbers in parentheses are predicted occurrence of a given combination, assuming independence; numbers not in parentheses are observed occurrence.

$n_i$ = Observed total number in row

$n_j$ = Observed total number in column

this group of 28 RIS cases, the probability of a very large reservoir is 6/28, of a large reservoir 11/28, and of a small reservoir 11/28. If depth and volume were unrelated, the probability of a reservoir being both very deep and very large would be 10/28 times 6/28. Multiplying this amount by the number of reservoirs (28) gives 2.14, which would be the expected number of reservoirs which are both very deep and very large, given no correlation between the attributes. This number is shown in parentheses in Table 2-5, beside the original data.

To examine whether, in fact, a correlation exists, the observed occurrences are tested for significant differences from the predicted occurrences assuming independence. One test method is with a Chi-squared ($X^2$) goodness-of-fit test. If the attributes were independent, the deviations observed from predicted frequencies could be predicted probabilistically. Thus, the actual deviations can be compared to these predictions; if the attributes would have been very unlikely given independence, then the attributes were in fact correlated. One Chi-square test involves the quantity

$$y = -2 \log \left[ \frac{\prod_{i}^{r} \left(n_i\right)^{n_i} \prod_{j}^{s} \left(n_j\right)^{n_j}}{\left(N^N\right) \prod_{i}^{r} \prod_{j}^{s} \left(n_{ij}\right)^{n_{ij}}} \right] \qquad (1)$$

where $y$ is a "statistic" of the data,
$n_{ij}$ is the number of occurrences in cell ij of the table,
$n_i$ is the number of occurrences along the row i,
$n_j$ is the number of occurrences along the column j,
$N$ is the total number of occurrences,
$r$ is the number of rows,
$s$ is the number of columns.

If the attributes were independent, the quantity would be distributed as a Chi-squared distribution with $[(r-1)(s-1)]$ degrees of freedom. Thus, the observed value of this statistic can be compared with published tables on $\chi^2$ to obtain its probability of exceedance for independent attributes.

In the example for depth and volume (given RIS), Equation (1) is used to calculate the statistic y from the data in Table 2-6, and y is found to be 0.38. Two degrees of freedom are associated with this test; from a Chi-squared table, when $\chi^2$ has two degrees of freedom, it is less than 5.99 for 95 percent of the time. Hence, it is unlikely that a statistic of 0.38 will be obtained in this case. Based on these discrete data, depth and volume are not strongly correlated for the RIS cases.

Chi-squared statistics for each attribute pair for both the accepted RIS and not-accepted RIS cases are shown in Table 2-6. Associated degrees of freedom are shown in parentheses. Based on these analyses, the data do not support conclusions of dependence between any attribute pair, for either the accepted RIS cases or the not-accepted RIS cases. The possible exception is depth/volume, and even this latter dependence is only weakly supported in the discrete data.

TABLE 2-6: TEST OF INDEPENDENCE IN CONTINGENCY TABLES.

$\chi^2$ Statistics for Discrete Attribute Combinations[a]

| | Depth | Volume | Stress | Faulting | Geology |
|---|---|---|---|---|---|
| Depth | | 4.6 (2) | 4.9 (4) | -- | 5.7 (4) |
| Volume | 0.38 (2) | | 5.7 (4) | -- | 4.5 (4) |
| Stress | 0.60 (4) | 2.38 (4) | | -- | 4.4 (4) |
| Faulting | -- | -- | -- | | -- |
| Geology | 2.7 (4) | 0.63 (4) | 1.8 (4) | -- | |

Not Accepted RIS Cases

Accepted RIS Cases

---

[a] Degrees of freedom associated with each test is indicated in parentheses (beside the associated statistic). A statistic greater than 9.49 is significant at the 95 percent level of confidence for four degrees of freedom, and a statistic greater than 5.99 is significant at that confidence level with two degrees of freedom.

Correlations Of Depth and Volume from Regression Analysis on Continuous Data

| Accepted RIS Case | Not-Accepted RIS Case |
|---|---|
| 0.07 for 28 reservoirs | 0.22 for 172 reservoirs |
| $t_{26} = 0.36$ | $t_{170} = 2.94$ |
| not significant at 95% | significant at 95% |

Unlike data for the other attributes, data on depth and volume for the 200 deep or very deep reservoirs were available as continuous variables. Regression analyses were performed to examine whether correlations between depth and volume were masked by the assignment to discrete categories of deep or very deep, and small, large, or very large reservoirs (see Table 2-6). The results indicate weak correlations in both the accepted RIS and not-accepted RIS cases. The correlation coefficient between depth and the logarithm of volume for the RIS case was 0.07 and for the not-accepted RIS case was 0.22. Given the respective size of the data sets, 28 and 172, only the correlation for the not-accepted RIS case is significant at the 95 percent level.

### 2.4.4 Relationship of RIS Microseismicity and Macroseismicity

In this section, microseismicity refers to sites which have had local RIS but no major events reported in worldwide catalogs. Macroseismicity refers to sites which have had RIS events, usually with magnitude greater than 3, reported by ISC or NOAA. The purpose here is to ascertain if a difference in attributes exists between sites which have had only microseismicity and those which have had macroseismicity. Chi-squared tests, similar to those above, were used. In particular, six pairs of data (faulting was excluded because of lack of data) for the macroseismicity sites were compared to the respective sets of data for the microseismicity sites. In Table 2-7, the Chi-squared test is illustrated to examine whether the depth/volume relationship is different for the macroseismicity and microseismicity sites. The Chi-squared statistics on all attribute correlations and associated degrees of freedom are reported in Table 2-8. None of the differences are significant at the 90 percent confidence level.

TABLE 2-7: ILLUSTRATION FOR DEPTH/VOLUME CORRELATION OF MACROSEISMIC VERSUS MICROSEISMIC EVENTS.

Macroseismic

| | | | |
|---|---|---|---|
| $d_1$ | 1 | 0 | 3 |
| $d_2$ | 4 | 7 | 3 |
| $d_3$ | 5 | 2 | 1 |
| | $v_3$ | $v_2$ | $v_1$ |

Microseismic

| | | | |
|---|---|---|---|
| $d_1$ | 3 | 1 | 1 |
| $d_2$ | 1 | 1 | 0 |
| $d_3$ | 3 | 2 | 0 |
| | $v_3$ | $v_2$ | $v_1$ |

$$\sum_{i}\sum_{j}\sum_{k} \frac{(n_{ijk} - N_k p_i p_j)^2}{N_k p_i p_j} \sim / \; \chi^2 \; (r-1)(s-1)^2$$

where:

$r$ = number of rows
$s$ = number of columns
$k$ = 1 for macroseismic data
$k$ = 2 for microseismic data

$n_{ijk}$ = number of occurrences in cell $ij$, table $k$

$p_i = \sum_k \sum_j \frac{n_{ijk}}{N}$ = fraction of all data in all tables $k$ that have attribute state $i$.

$p_j = \sum_k \sum_i \frac{n_{ijk}}{N}$ = fraction of all data in all tables $k$ that have attribute state $j$

$N_k$ = number in data table

$N$ = total number in both tables

---

Reference: Kendall, M. G., and Stuart, A., 1973, The Advanced Theory of Statistics: Hafner, London, Third Edition, v. 2.

TABLE 2-8: $\chi^2$ FOR MACROSEISMIC VERSUS MICROSEISMIC DATA.[a]

| | $\chi^2$ |
|---|---|
| depth - volume | 10.04 |
| depth - stress | 11.18 |
| depth - faulting | (b) |
| depth - geology | 9.69 |
| volume - stress | 7.96 |
| volume - faulting | (b) |
| volume - geology | 9.64 |
| stress - faulting | (b) |
| stress - geology | 6.52 |
| faulting - geology | (b) |

---

[a] Eight degrees of freedom are associated with each test. A statistic greater than 13.4 is significant at the 90 percent level and greater than 15.5 is significant at the 95 percent level.

[b] Not analyzed because of lack of data.

### 2.4.5 Shallow Compared to Deep and Very Deep RIS Reservoirs

The attributes associated with shallow reservoirs with accepted RIS were compared to those associated with deep and very deep reservoirs with accepted RIS. Chi-squared statistics for pairs of attributes involving volume, stress, and geology were calculated. Faulting was not analyzed because of the lack of data. Corresponding data tables, showing Chi-squared statistics and associated degrees of freedom, for the various pairs of attributes are presented in Table 2-9. The only significant distinction between shallow RIS and deep/very deep RIS reservoirs is the volume and stress pair of attributes, which is significant at the 95 percent confidence level.

## 2.5 A PRELIMINARY STATISTICAL MODEL OF RESERVOIR INDUCED SEISMICITY

From the statistical data base, a preliminary model to predict the likelihood of reservoir induced seismicity, based upon various attribute states, can be provided. For this study, the term "prior probability" refers to the likelihood of the occurrence of RIS out of all the reservoirs considered, and "conditional probability" means the probability of RIS occurring at a reservoir characterized by particular attribute states.

The probability of RIS for a reservoir categorized by the state of only one attribute was first analyzed. The association of different states of each attribute as they individually relate to the occurrence of RIS was examined. In order to calculate the probability of RIS for the states of all attributes, this information was first combined in a model that assumes probabilistic independence of the attributes. Because of the correlation between depth and volume implied by

TABLE 2-9: SHALLOW COMPARED TO DEEP AND VERY DEEP RIS RESERVOIRS.

| Shallow Reservoirs | | | | Deep/Very Deep Reservoirs | | | |
|---|---|---|---|---|---|---|---|
| $s_3$ | 0 | 1 | 2 | $s_3$ | 2 | 1 | 2 |
| $s_2$ | 4 | 2 | 1 | $s_2$ | 8 | 3 | 5 |
| $s_1$ | 0 | 2 | 1 | $s_1$ | 2 | 2 | 0 |
| | $g_1$ | $g_2$ | $g_3$ | | $g_1$ | $g_2$ | $g_3$ |

$\chi^2$ = 10.55
$\chi^2$ (90%) = 13.4
$\chi^2$ (95%) = 15.5

| Shallow Reservoirs | | | | Deep/Very Deep Reservoirs | | | |
|---|---|---|---|---|---|---|---|
| $v_3$ | 3 | 3 | 2 | $v_3$ | 5 | 1 | 3 |
| $v_2$ | 1 | 2 | 1 | $v_2$ | 3 | 3 | 3 |
| $v_1$ | 0 | 0 | 1 | $v_1$ | 4 | 2 | 1 |
| | $g_1$ | $g_2$ | $g_3$ | | $g_1$ | $g_2$ | $g_3$ |

$\chi^2$ = 7.32
$\chi^2$ (90%) = 13.4
$\chi^2$ (95%) = 15.5

| Shallow Reservoirs | | | | Deep/Very Deep Reservoirs | | | |
|---|---|---|---|---|---|---|---|
| $v_3$ | 0 | 6 | 2 | $v_3$ | 0 | 7 | 2 |
| $v_2$ | 3 | 1 | 0 | $v_2$ | 1 | 6 | 2 |
| $v_1$ | 0 | 0 | 1 | $v_1$ | 3 | 3 | 1 |
| | $s_1$ | $s_2$ | $s_3$ | | $s_1$ | $s_2$ | $s_3$ |

$\chi^2$ = 20.28
$\chi^2$ (90%) = 13.4
$\chi^2$ (95%) = 15.5

(continued)

TABLE 2-9: (continued)

Single Attribute Differences

| | Shallow | Deep/Very Deep | | |
|---|---|---|---|---|
| $s_1$ | 3 | 4 | | |
| $s_2$ | 7 | 16 | $\chi^2$ | = 0.42 |
| $s_3$ | 3 | 5 | $\chi^2$ (90%) | = 7.8 |
| $v_3$ | 8 | 9 | | |
| $v_2$ | 4 | 9 | $\chi^2$ | = 3.44 |
| $v_1$ | 1 | 7 | $\chi^2$ (90%) | = 7.8 |
| $g_1$ | 4 | 12 | | |
| $g_2$ | 5 | 6 | $\chi^2$ | = 1.38 |
| $g_1$ | 4 | 7 | $\chi^2$ (90%) | = 7.8 |

the analyses shown in Section 2.4.3 of this report, models were also developed for estimating the probability of RIS given this dependence. In particular, two specific dependent cases were analyzed: one based on correlation between discrete depth and volume, and the other based on correlations between continuous depth and volume. Finally, all three models--the independent model, the discrete dependent model, and the mixed discrete/continuous model--were used for typical calculations for reservoir induced seismicity.

### 2.5.1 Single Attribute Analysis

If the state of one attribute, such as depth, is known, then the conditional probability of RIS can be calculated by using Bayes' Theorem:

$$P(RIS|d_i) = \frac{P(RIS)P(d_i|RIS)}{P(RIS)\ P(d_i|RIS) + P(\overline{RIS})\ P(d_i|\overline{RIS})} \qquad (2)$$

| | |
|---|---|
| where $d_i$ | is the depth, |
| $P(RIS)$ | is the prior probability (frequency) of an accepted RIS case, |
| $P(\overline{RIS})$ | is the prior probability of a not-accepted RIS case, |
| $P(d_i|\overline{RIS})$ | is the conditional probability of depth $d_i$ for an accepted RIS case and, |
| $P(d_i|RIS)$ | is the conditional probability of $d_i$ for a not-accepted RIS case. |

For the 234 deep, very deep and/or very large reservoirs, the prior probability P(RIS) of reservoir induced seismicity is 29/234 or 0.12. Consequently, the prior probability of not-accepted RIS [$P(\overline{RIS})$] is 0.88. Using this and the data in Table 2-3, the conditional probability of RIS, given any specific state of a single attribute, can be calculated. As an illustration, a very deep reservoir (State $d_i = d_1$) can be used. Equation (2) then becomes

$$P(RIS \mid d_1) = \frac{P(RIS) \quad P(d_1 \mid RIS)}{P(RIS) \quad P(d_1 \mid RIS) + P(\overline{RIS}) \quad P(d_1 \mid \overline{RIS})}$$

$$= \frac{(0.12) \quad (0.34)}{(0.12) \ (0.34) + (0.88) \ (0.13)}$$

$$= \quad 0.26 \qquad (3)$$

The number 0.26 is the conditional probability of RIS for a very deep reservoir. All other conditional probabilities for RIS are shown in Table 2-10. From this table, it appears that the main attribute indicating whether a particular reservoir has potential for RIS is depth. Volume is the next most indicative attribute. The stress and geology attributes are not nearly as strong indicators, since the conditional probabilities of these attributes for RIS and not-accepted RIS are rather similar. Sufficient data are not available to give statistical meaning to any conditional probability for the faulting attribute states.

### 2.5.2 Multiattribute Model

The multiattribute model, which is analogous to Equation (2), considers all attributes simultaneously:

$$P(RIS \mid d,v,s,f,g) = \frac{P(RIS) \ P(d,v,s,f,g \mid RIS)}{P(RIS) \ P(d,v,s,f,g \mid RIS) + P(\overline{RIS}) \ P(d,v,s,f,g \mid \overline{RIS})}; \quad (4)$$

and,

$$P(RIS \mid d,v,s,f,g) = \frac{P(RIS) \ P(d,v,s,f,g \mid RIS)}{P(RIS) \ P(d,v,s,f,g \mid RIS) + P(\overline{RIS}) \ P(d,v,s,f,g \mid \overline{RIS})}; \quad (5)$$

TABLE 2-10: CONDITIONAL PROBABILITIES OF RIS FOR ONLY ONE ATTRIBUTE.[a]

| Attribute | State<br>1 | <br>2 | <br>3 |
|---|---|---|---|
| Depth | 0.27 (0.24) | 0.11 (0.10) | 0.03 (0) |
| Volume | 0.12 (0.22) | 0.23 (0.21) | 0.09 (0.07) |
| Stress State | 0.10 (0.11) | 0.12 (0.14) | 0.18 (0.17) |
| Fault Activity | 0.18 (0.20) | 0.00 (0.00) | -- |
| Geology | 0.16 (0.20) | 0.10 (0.10) | 0.12 (0.12) |

---

[a] The numbers not in parentheses are based on the deep, very deep and/or very large data set. Conditional probabilities (in parentheses) are based on deep and very deep data only.

where $P(RIS|d,v,s,f,g)$ is the conditional probability of RIS given the combination of states d,v,s,f,g. Dividing Equation (4) by Equation (5) yields

$$\frac{P(RIS|d,v,s,f,g)}{P(\overline{RIS}|d,v,s,f,g)} = \frac{P(RIS)\ P(d,v,s,f,g|RIS)}{P(\overline{RIS})\ P(d,v,s,f,g|\overline{RIS})} \qquad (6)$$

The statement of Equation (6) is "the conditioned odds of RIS equals the prior odds of RIS, multiplied by the likelihood ratio for the given states." Equations (4) and (6) are the bases for all the models that predict the likelihood of RIS.

### 2.5.3 Preliminary Model of RIS Assuming Probabilistic Independence

Assuming probabilistic independence among all attributes, the conditional probabilities of Equations (4) and (6) become, respectively,

$$P(d,v,s,f,g|RIS) = P(d|RIS)\ P(v|RIS)\ P(s|RIS)\ P(f|RIS)\ P(g|RIS) \qquad (7)$$

and

$$P(d,v,s,f,g|\overline{RIS}) = P(d|\overline{RIS})\ P(v|\overline{RIS})\ P(s|\overline{RIS})\ P(f|\overline{RIS})\ P(g|\overline{RIS}) \qquad (8)$$

The terms such as $P(d|RIS)/P(d|\overline{RIS})$ are referred to as individual likelihood ratios, which are calculated from Table 2-3 and displayed in Table 2-11. To use the independent model, the information from Table 2-11, along with the prior probabilities of accepted RIS and not-accepted RIS, is substituted into Equations (7) and (8) and then into either Equation (4) or Equation (6). Examples are included at the end of this section.

TABLE 2-11: LIKELIHOOD RATIOS - INDEPENDENT CASE.[a]

| | State | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Depth | 2.62 (2.26) | 0.87 (0.76) | 0.21 |
| Volume | 0.95 (2.04) | 2.15 (1.87) | 0.66 (0.57) |
| Stress | 0.82 (0.74) | 0.91 (1.00) | 1.58 (1.29) |
| Fault Activity | 1.50 (1.50) | 0.00 (0.00) | -- |
| Geology | 1.34 (1.55) | 0.74 (0.71) | 0.94 (0.81) |

---

[a] The likelihood ratios (in parentheses) are based on deep and very deep reservoir data only.

If different subsets of the data are considered, for example deep and very deep instead of deep, very deep, and/or very large, both the prior probabilities and likelihood ratios change. However, except for the cells in the data matrix which are added or removed, the prior probabilities and likelihood ratios change such that the final result is unchanged (as can be seen in Table 2-10). This is not necessarily true in the dependent case.

### 2.5.4 Models of RIS Assuming Dependence Between Depth and Volume

A model, very similar to that above, was developed for volume and depth as not probabilistically independent. Therefore,

$$P(d,v,s,f,g|RIS) = P(d,v|RIS)\ P(s|RIS)\ P(f|RIS)\ P(g|RIS) \qquad (9)$$

and

$$P(d,v,s,f,g|\overline{RIS}) = P(d,v|\overline{RIS})\ P(s|\overline{RIS})\ P(f|\overline{RIS})\ P(g|\overline{RIS}) \qquad (10)$$

where $P(d,v|RIS)$ means the joint probability of certain values of depth and volume, given that RIS occurred.

For the discrete case, this information can be estimated directly from the data sets. For instance, for the 29 cases of accepted RIS, 3 cases were both very deep and large (i.e., $D = d_1$ and $V = v_2$). Thus, the conditional probability of this combination for RIS is estimated as 3/29 or 0.11. In a similar manner, the conditional probability of a very deep and large reservoir in a not-accepted RIS case is estimated as 11/204 or 0.06. The likelihood ratio for the $d_1$, $v_2$ combination is the ratio of these numbers. This ratio and the likelihood ratios of all volume and depth combinations are shown in Table 2-12.

TABLE 2-12: LIKELIHOOD RATIOS - DEPENDENT CASE.

Discrete Case - Depth and Volume[a]

| | Volume | | |
|---|---|---|---|
| Depth | Small | Large | Very Large |
| very deep | 2.56 (2.22) | 1.92 (1.67) | 4.22 (3.66) |
| deep | 0.46 (0.40) | 2.25 (1.95) | 1.62 (1.41) |
| shallow | -- | -- | 0.21 |

Continuous Case: Depth and Volume[b]

$$LR(d,v) = \frac{f_N(d,v \mid \mu_d = 141,\ \mu_v = 3.21;\ \sigma_d = 48.8,\ \sigma_v = 1.0,\ \rho = 0.2)}{f_N(d,v \mid \mu_d = 124,\ \mu_v = 2.78;\ \sigma_d = 26.8,\ \sigma_v = 0.88,\ \rho = 0.2)}$$

Both Cases: Stress, Faulting, and Geology[a]

| | State | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Stress | 0.82 (0.74) | 0.91 (1.0) | 1.58 (1.29) |
| Faulting | 1.50 (1.50) | 0 (0.0) | -- |
| Geology | 1.34 (1.55) | 0.74 (0.71) | 0.94 (0.81) |

---

[a] Likelihood ratios (in parentheses) refer to deep and very deep reservoir data set.

[b] $f_n(\cdot|\cdot)$ indicates a Normal distribution with parameters as given, following the bar. These parameters are the following:

$\mu_d$ = Mean of depth
$\mu_v$ = Mean of volume
$\sigma_d$ = Standard deviation, depth
$\sigma_v$ = Standard deviation, volume
$\rho$ = Correlation coefficient

Equations (9) and (10) are useful for calculating the probability of reservoir induced seismicity from discrete, although dependent, information on volume and depth. A similar model was developed for volume and depth as continuous variables. For the deep and very deep reservoirs, regression models were run for both the accepted RIS and not-accepted RIS cases to fit bivariate, normal distributions, based upon dependence between the two attributes. Using these two distributions, the relative likelihood ratio of the occurrence of a particular d and v pair for the accepted RIS and not-accepted RIS cases can be obtained. This likelihood ratio is LR(v,d), which is also given in Table 2-12. The likelihood ratio from the continuous data in Equation (6) can be used to calculate the relative conditional probabilities of accepted RIS versus not-accepted RIS for a particular reservoir. Because these probabilities must sum to one, it is easy to calculate the conditional probability of RIS from this information.

### 2.5.5 Typical Calculations for the Probability of Reservoir Induced Seismicity

The likelihood Equation (6) can be used to calculate the probability of RIS for all three models: the independent model, the discrete dependent model, and the mixed discrete/continuous dependent model. Two examples are provided to illustrate the technique.

1) A very deep, large reservoir is in an extensional stress field; active faulting is present, and metamorphic geology is characteristic of the reservoir area. Notationally this corresponds to a designation of ($d_1$, $v_2$, $s_1$, $f_1$, $g_2$). For the independent model, the data from Table 2-11 can be substituted into Equation (6) to calculate the conditional probability of reservoir induced seismicity, which is 0.35. Using the

discrete dependent model, data from Table 2-12 are applied to Equations (9) and (10) then into Equation (6) to find that the conditional probability of reservoir induced seismicity for example one is 0.17. For the continuous model for depth and volume (assumed depth of 183 m and a volume of 30 x $10^8$ $m^3$), the likelihood ratio in Table 2-12 is substituted into Equation (6), and the conditional probability of reservoir induced seismicity for this first example is found to be 0.32. The basic data for all three of these calculations are shown in Table 2-13. These conditional probabilities are the same for both data sets as changes in the attribute likelihood ratios are compensated by changes in the prior probabilities.

To assess the accuracy of the estimate of 0.35 for the probability of RIS in this first example (independent case), a sampling variance of the estimate has been calculated (Table 2-14). The corresponding standard deviation is 0.14, which implies that the estimate is not precise. The procedure for calculating the sampling variance of the estimate of probability of RIS is as follows. The sampling of each marginal likelihood can be calculated from the Bernoulli model:

$$V[p_i] = \hat{p}(1-p_i)/n$$

where $\hat{p}_i$ is the estimate of the probability of attribute level i, given RIS. These estimates are propagated through Bayes' Theorem for estimating the conditional probability of RIS for the various attribute values. Because the uncertainty in the estimates are multiplied, the aggregate uncertainty increases over the uncertainty in any one likelihood.

2) The second example is a deep and large reservoir having extensional stress, active faulting, and sedimentary geology. The predicted likelihood for the occurrence of RIS was

## TABLE 2-14: SAMPLING VARIANCE: EXAMPLE ONE, DISCRETE MODEL[a]

### Variance of Attribute Likelihoods

| Attribute | Variance | Coefficient of Variation (COV) |
|---|---|---|
| very deep | $8.2 \times 10^{-3}$ | 0.25 |
| large | 8.5 | 0.23 |
| extensional | 4.3 | 0.46 |
| active | -- | |
| metamorphic | 7.8 | 0.30 |

### Variance of Numerator and Demoninator[b]

$$\begin{aligned}
\hat{P} &= \hat{p}^{o}(\mathrm{RIS})\ \hat{L}(d_1|\mathrm{RIS})\ \hat{L}(v_2|\mathrm{RIS})\ \hat{L}(s_1|\mathrm{RIS})\ \hat{L}(g_2|\mathrm{RIS}) \\
\hat{Q} &= \hat{p}^{o}(\overline{\mathrm{RIS}})\ \hat{L}(d_1|\overline{\mathrm{RIS}})\ \hat{L}(v_2|\overline{\mathrm{RIS}})\ \hat{L}(s_1|\overline{\mathrm{RIS}})\ \hat{L}(g_2|\overline{\mathrm{RIS}}) \\
\mathrm{COV}\ \hat{P} &= \{\ \mathrm{COV}^2\hat{p}^{o} + \mathrm{COV}^2\hat{L}_d + \mathrm{COV}^2\hat{L}_v + \mathrm{COV}^2\hat{L}_s + \mathrm{COV}^2\hat{L}_g\ \} = 0.67 \\
\mathrm{COV}\ \hat{Q} &= \{\ \mathrm{COV}^2\hat{q}^{o} + \mathrm{COV}^2\hat{L}_{d'} + \mathrm{COV}^2\hat{L}_{v'} + \mathrm{COV}^2\hat{L}_{s'} + \mathrm{COV}^2\hat{L}_{g'}\} = 0.30 \\
&\quad \text{where, } \hat{p}^{o} = \hat{p}^{o}(\mathrm{RIS});\ \hat{q}^{o} = \hat{p}^{o}(\overline{\mathrm{RIS}});\ \hat{L}_d = L(d|\mathrm{RIS});\ \text{and } \hat{L}_{d'} = L(d|\overline{\mathrm{RIS}}) \\
C(\hat{P}+\hat{Q}) &= C(\hat{p}^{o},\hat{q}^{o})\cdot\hat{L}_d\cdot\hat{L}_v\cdot\hat{L}_s\cdot\hat{L}_g\cdot\hat{L}_{d'}\cdot\hat{L}_{v'}\cdot\hat{L}_{s'}\cdot\hat{L}_{g'} \\
V(\hat{P}) &= 2.7 \times 10^{-7} \\
V(\hat{Q}) &= 3.1 \times 10^{-7} \\
(\hat{P},\hat{Q}) &= 7.3 \times 10^{-9}, \quad \text{where } C(\hat{P},\hat{Q}) \text{ is the covariance of } \hat{P} \text{ and } \hat{Q}.
\end{aligned}$$

### Estimator Variance

$$\begin{aligned}
\hat{P}r(\mathrm{RIS}) &= \hat{P}/(\hat{P}+\hat{Q}) \\
V(\hat{P}r) &= \{(\hat{P}+\hat{Q})^{-1} - \hat{P}/(\hat{P}+\hat{Q})^2\}^2\cdot V(\hat{P}) + \{\hat{P}/(\hat{P}+\hat{Q})^2\}^2\cdot V(\hat{Q}) \\
&\qquad + \{(\hat{P}+\hat{Q})^{-1} - \hat{P}/(\hat{P}+\hat{Q})^2\}\{\hat{P}/(\hat{P}+\hat{Q})^2\}\cdot C(\hat{P},\hat{Q}) \\
&= 2.3 \times 10^{-2} \\
\sigma(\hat{P}r) &= 0.15
\end{aligned}$$

---

[a] Analysis for deep and very deep data set.

[b] Reference: Kendall and Stuart, 1973 (cf. Table 2-7).

TABLE 2-13: DATA USED FOR EXAMPLE ONE CALCULATIONS.[a]

| | Likelihood Ratio | | |
|---|---|---|---|
| States | Discrete independent | Discrete dependent | Mixed discrete/ continuous dependent |
| Very Deep | 2.26 | 1.67 | 3.72 |
| Large | 1.87 | | |
| Extensional | 0.74 | 0.74 | 0.74 |
| Active | 1.50 | 1.50 | 1.50 |
| Metamorphic | 0.71 | 0.71 | 0.71 |
| Cumulative product ($\Pi$) = | 3.33 | 1.32 | 2.93 |

CONDITIONAL ODDS RATIO:

- Prior odds ratio = 0.14/0.86 = 0.16
- Conditional odds ratio:

  independent = 0.16 x 3.33 = 0.53
  dependent discrete = 0.16 x 1.32 = 0.21
  dependent mixed = 0.16 x 2.93 = 0.47

- Conditional Probability of RIS:

  independent = 0.53/1.53 = 0.35
  dependent discrete = 0.21/1.21 = 0.17
  dependent mixed = 0.47/1.47 = 0.32

---

[a] Based on deep and very deep data set.

examined and is indicated in Table 2-15. The characteristics of those reservoirs corresponding to the least likely and most likely to be associated with RIS are also indicated in Table 2-15. The calculations illustrate the range of probabilities that can be generated by these models.

## 2.6 INTERPRETATION AND APPRAISAL

### 2.6.1 Interpretation of the Results

Several observations can be made from the results of this statistical analysis. First, depth appears to be the most discriminating attribute among the five attributes studied (Table 2-10). (The data set for this analysis does not accurately reflect the conditional probability for RIS at shallow reservoirs; only shallow reservoirs that are also very large were considered. If all 13,000 or more shallow reservoirs were considered, the conditional probability for RIS at a shallow reservoir would be near zero.)

The next best attribute for distinguishing between accepted RIS and not-accepted RIS cases appears to be reservoir volume. Only very large reservoirs were considered completely; if all large and small reservoirs were considered, the appropriate conditional probabilities would be much lower (see Stuart-Alexander and others, 1979). The reason for the higher conditional probability of RIS for large reservoirs, as compared to very large reservoirs (Table 2-10), is that the only large reservoirs analyzed in this study are those that are deep or very deep, while all very large reservoirs were analyzed. If the 33 very large but shallow reservoirs are excluded from the data set, the conditional probability of RIS for a very large reservoir becomes 0.22, instead of 0.12.

TABLE 2-15: SAMPLE CALCULATIONS FOR EXAMPLE 2, BEST CASE AND WORST CASE.

| | Example Two (deep[a], large, extentional, active, sedimentary) | | Best Case (deep[a], small, extentional no activity, metamorphic) | | Worst Case (very deep[a], very large, shear, active, sedimentary) | |
|---|---|---|---|---|---|---|
| | independent | discrete dependent | independent | discrete dependent | independent | discrete dependent |
| Depth | 0.76 | 1.95 | 0.76 | 0.40 | 2.26 | 3.66 |
| Volume | 1.87 | | 0.57 | | 2.04 | |
| Stress | 0.74 | 0.78 | 0.78 | 0.78 | 1.29 | 1.29 |
| Faulting | 1.50 | 1.50 | (b) | (b) | 1.50 | 1.50 |
| Geology | 1.55 | 1.55 | 0.71 | 0.71 | 1.55 | 1.55 |
| Cumulative Product = | 2.45 | 3.55 | 0.24 | 0.22 | 13.8 | 11.0 |
| Prior Odds Ratio | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| Conditonal Odds Ratio | 0.40 | 0.58 | 0.04 | 0.04 | 2.26 | 1.80 |
| Conditional Probability of RIS | 0.29 | 0.37 | 0.04 | 0.03 | 0.69 | 0.64 |

[a] Shallow reservoirs disallowed.

[b] Empty data cell has likelihood ratio of zero. Because this calculation is based on a very small data set, the likelihood ratio is assumed to be 1.0.

The continuous analysis of depth and volume revealed a weak correlation between these attributes for not-accepted RIS sites. No other significant correlations have been observed. Accordingly, the continuous/discrete statistical model is the strongest of the three predictive models because it includes the dependence between depth and volume.

Very little can be concluded statistically about the relevance of the attribute of active faulting because few data were gathered on the presence of active faults near reservoirs and because of the difficulty in assessing fault activity at many sites where no specific fault studies have been conducted. As a final observation on the statistical analysis, a cause and effect relationship should not be assumed between the attributes studied and the likelihood of reservoir induced seismicity.

### 2.6.2 Appraisal of the Data and Sensitivity Analysis

The size of the data set has a major impact on the significance of the results. Many of the conclusions in this study were drawn from a set of 234 reservoirs, 29 of which are accepted cases of reservoir induced seismicity. Although this total size is fairly large, 162 (3 x 3 x 3 x 2 x 3) possible combinations of attribute states means that the information about various combinations of attribute levels is quite sparse. This situation is particularly acute when only 29 reservoirs are considered. Also, because of the magnitude of the data collection problem, more than 13,000 reservoirs, which are neither deep, very deep, nor very large, were excluded from this study.

The classification of the characteristics at each reservoir requires professional judgment of the available data. Additional data on site-specific conditions may prove some of these judgments inaccurate. For some attributes, changes in only a few reservoir classifications, particularly for the accepted RIS cases, can have a significant impact on the predictive model. The following example, using data from Table 2-3(A), illustrates the sensitivity of the results to changes in the data.

If three of the RIS reservoirs were transferred from shear status (state $s_3$) to extensional status (state $s_1$), the conditional probabilities for shear and extensional stress regimes, given RIS, would become 0.11 and 0.17, respectively (cf. Table 2-10). Such a change would reverse the conclusions drawn from the data, making an extensional stress regime the most likely to be associated with RIS, rather than shear.

The choice of cutoff levels for depth and volume also can influence the results of discrete analyses. Table 2-16 illustrates the changes in conditional probabilities if the cutoff of very deep reservoirs were chosen at 175 m instead of 150 m. The 175-m cutoff was selected as an alternative because many of the reservoirs with depths between 150 m and 175 m are not-accepted RIS cases.

Whether or not a reservoir is classified as a case of accepted RIS will affect the analysis. For example, if ten reservoirs now classified as accepted RIS were reclassified as not-accepted RIS, all the estimated probabilities for RIS using Equation (4) would be reduced by approximately one-third. Conversely, if ten of the not-accepted RIS cases were changed to accepted RIS, the resulting 30 percent increase in the RIS data base could change much of the significance in correlations observed in this study.

The limitation in the size of the data set and the sensitivity of the analysis to changes in data values require that this

TABLE 2-16: SENSITIVITY ANALYSIS OF DEFINITIONS FOR DEPTH STATES.[a]

| | State | | | |
|---|---|---|---|---|
| | Number of Reservoirs | Deeper than 175 m | 92 to 175 m | Less than 92 m |
| RIS data | 29 | 8 | 20 | 1 |
| RIS likelihood | | 0.28 | 0.69 | 0.03 |
| Not-accepted RIS data | 204 | 12 | 159 | 33 |
| Not-accepted PIS likelihood | | 0.06 | 0.78 | 0.16 |
| Likelihood ratio | | 4.69 | 0.88 | 0.21 |
| Conditional probability of RIS | | 0.40 | 0.11 | 0.03 |

---

[a] Alternative definition chosen for very deep.

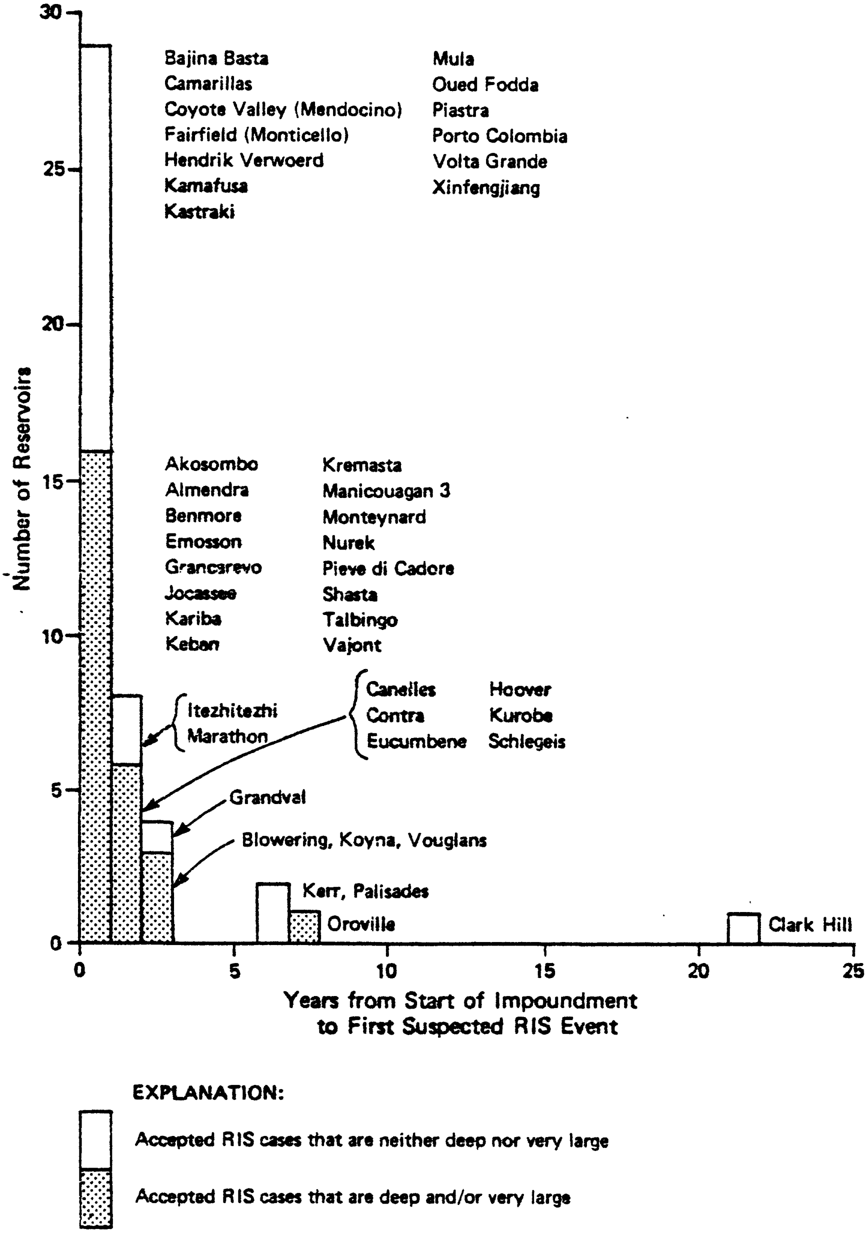
analysis be considered preliminary. The statistical models either consider all attributes to be independent or allow a dependence between depth and volume, assuming independence among the pair and each of the other attributes. More data or more accurate site-specific data could indicate dependence among other attributes. Such changes in recognized dependencies could then be incorporated into the general statistical model for assessing the likelihood of occurrence of reservoir induced seismicity.

## 2.7 ADDITIONAL OBSERVATIONS

In addition to the results of the statistical evaluation and categorization of reported cases of reservoir induced seismicity, observations of several other aspects of RIS can be made from the data. A plot of the time between the start of impoundment and the first suspected RIS event shows that nearly two-thirds (29 out of 45) of the accepted cases of RIS had suspected RIS during the first year (Figure 2-11). A similar pattern (10 out of 28) can be observed for accepted cases of RIS at deep and/or very large reservoirs.

A comparison of the time between impoundment and the first suspected RIS event to the time between impoundment and the largest suspected RIS event shows a time lag of, frequently, several years between first event and largest event to date (Figures 2-11 and 2-12). Generally, this delay between first and largest suspected RIS event is less than one year, although 9 reservoirs had delays of three years or more.

The distribution of magnitude of the maximum RIS events is shown on Figure 2-13. This graph may reflect the lack of monitoring of microearthquakes at many of the world's reservoirs; the expected distribution should have a relatively larger number of smaller magnitude events. All the reservoir



PLOT OF TIME BETWEEN IMPOUNDMENT AND FIRST SUSPECTED RIS EVENT

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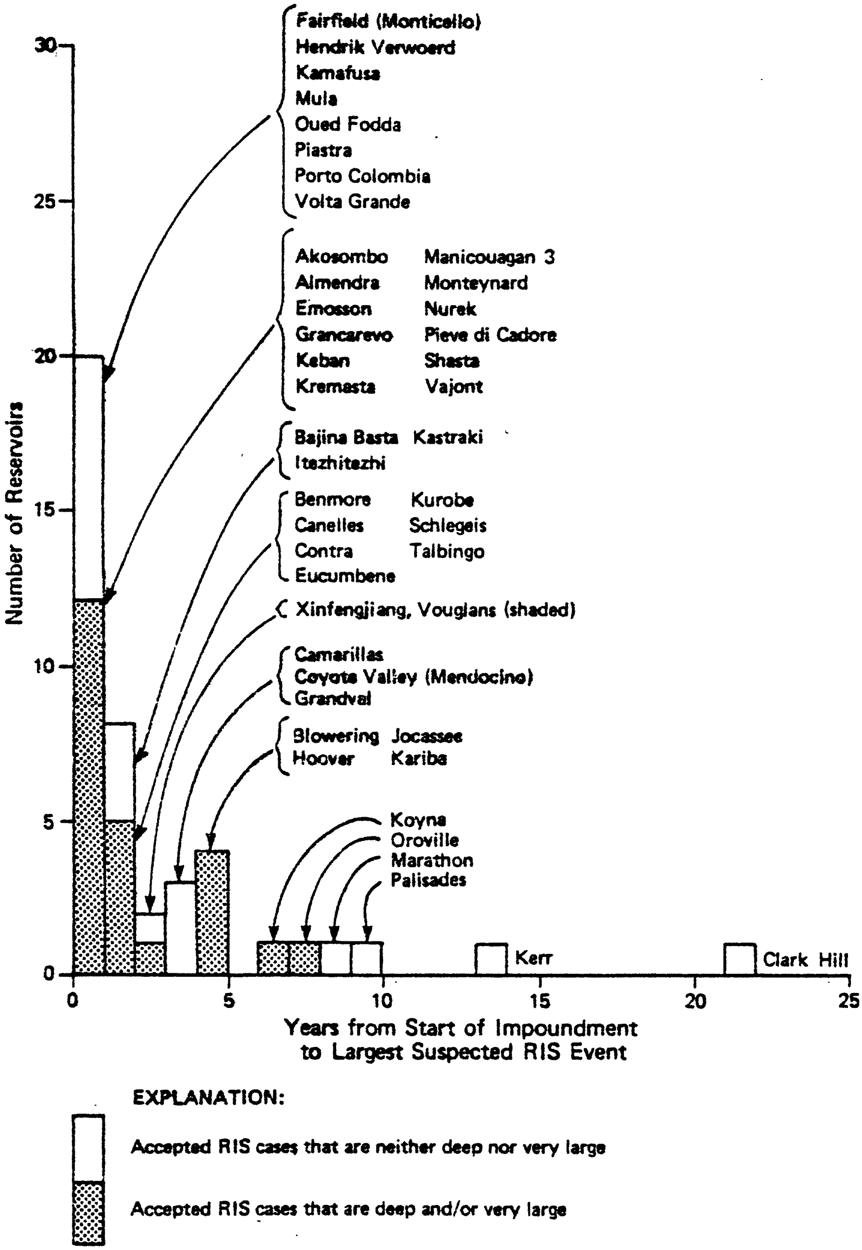
Figure 2-11

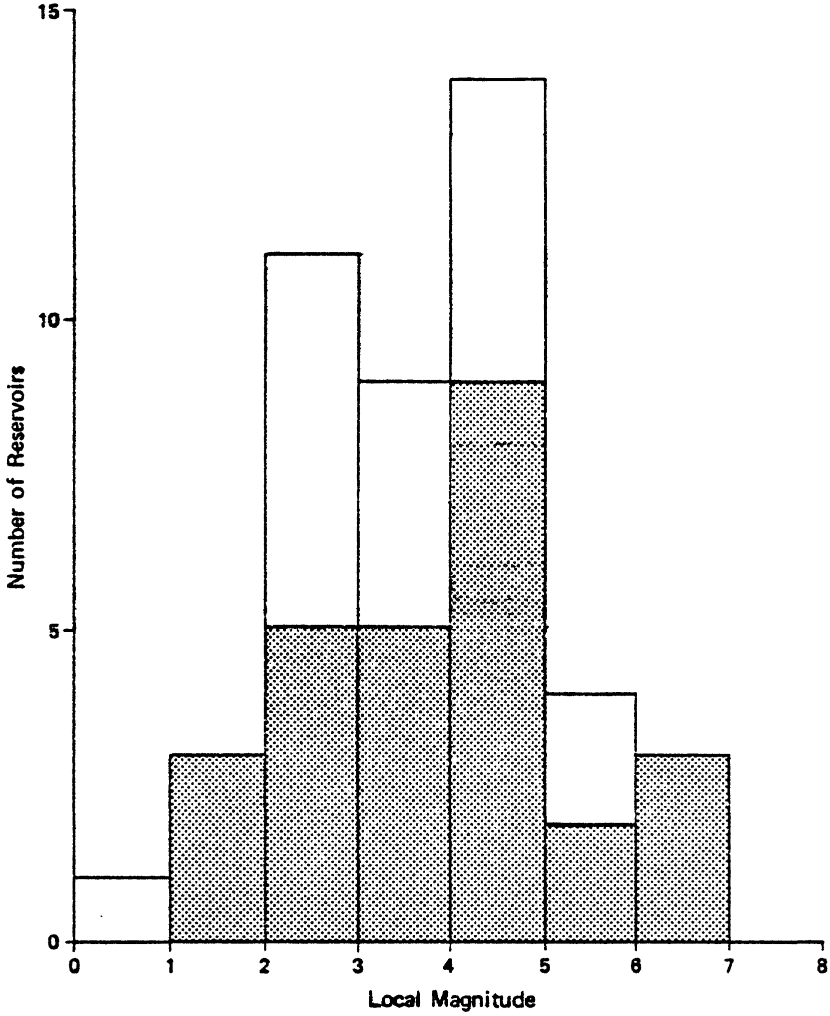


PLOT OF TIME BETWEEN IMPOUNDMENT AND LARGEST SUSPECTED RIS EVENT

Project No. 14087A

**Woodward-Clyde Consultants**

Figure 2-12



**EXPLANATION:**

☐ Accepted RIS cases that are neither deep nor very large

▨ Accepted RIS cases that are deep and/or very large

NOTE:
Refer to Table 1-1 for listing of reservoirs and magnitudes.

PLOT OF MAXIMUM MAGNITUDES OF
ACCEPTED RIS EVENTS

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**Woodward-Clyde Consultants**

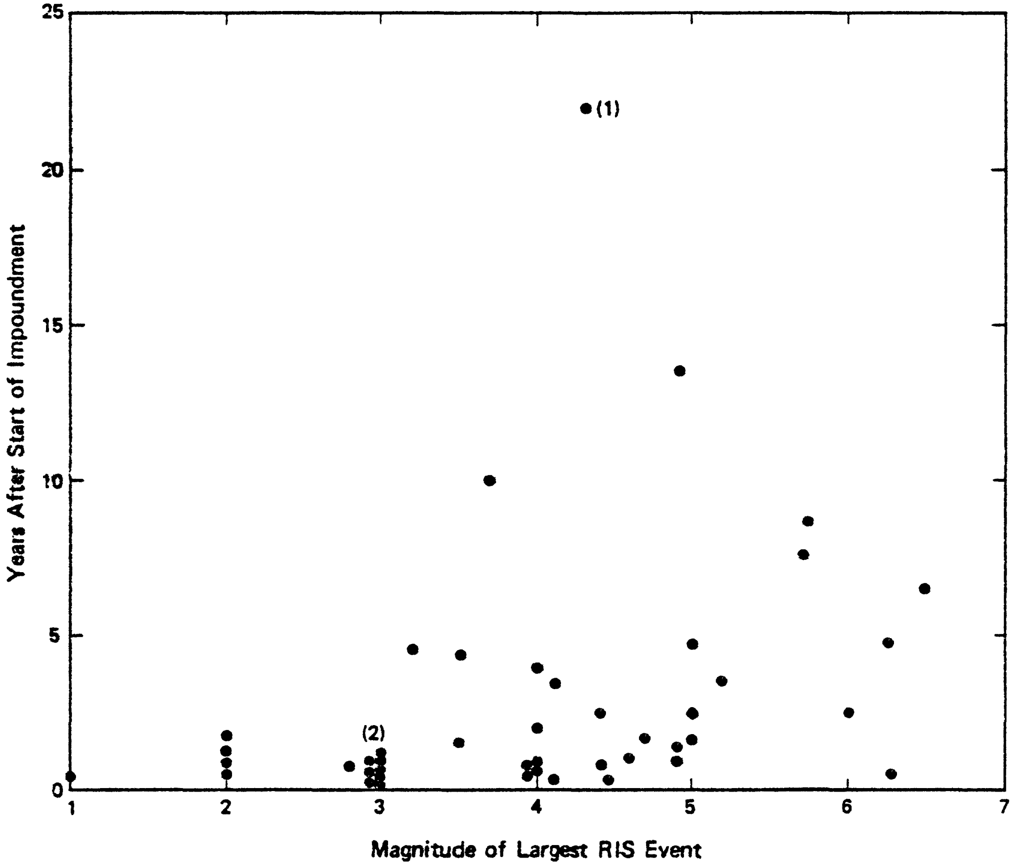
Figure 2-13

induced seismic events over magnitude 6 have occurred at deep and/or very large reservoirs. There also appears to be a relationship between a larger number of years after start of impoundment and larger magnitude RIS events (Figure 2-14). All RIS cases with maximum magnitudes of 3 or less (14 cases) occurred within 2 years after start of impoundment. RIS cases with maximum magnitude of 5.5 or greater (6 cases) have a mean of 5.1 years after start of impoundment, and only two of these occurred in less than two years.

## 2.8 SUMMARY AND CONCLUSIONS

A detailed literature survey was made to gather data on reported cases of reservoir induced seismicity and all deep and/or very large reservoirs. Deep and/or very large reservoirs were identified from the World Register of Dams and other compilations such as Mermel (1978) and Simpson (1976). Data were gathered from engineering literature for reservoir size and shape, reservoir impoundment, and water fluctuation history, and from geologic literature for regional and local geology, stress conditions and faulting, hydrology, and seismicity. Reported cases of RIS were identified from published accounts as well as from correspondence and discussions with various experts. The body of data resulting from this compilation is presented in Appendix A. These data have formed the basis for analysis of each case of RIS and for construction of preliminary statistical models to predict the occurrence of RIS.

The influence of the reservoir on local macro- and micro-seismicity has been evaluated for each reported case of RIS. Where post-impoundment seismicity had a demonstrable spatial and/or temporal relationship to the reservoir, the case for RIS is classified as accepted. Where it was clearly established as being unrelated to the reservoir, the case is



**NOTES:**

(1) Magnitude 4.3 event at Clark Hill may not have been reservoir induced; next largest event: M 2.7.

(2) Largest event is a microearthquake (magnitude unknown) for 8 reservoirs included at M 3.

| PLOT OF MAGNITUDE OF LARGEST RIS EVENT VERSUS TIME AFTER IMPOUNDMENT OF ACCEPTED CASES OF RIS | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 2-14<br>Page 78 |

classified as not accepted RIS. Where the relationship is unclear because of insufficient data, the case is classified as questionable RIS. Of the 64 reported cases of RIS considered, 45 were assessed to have accepted RIS and 7 were assessed to be not reservoir induced. Of these 45 cases, 16 were recognized as accepted RIS at macro- and micro-seismicity levels, 14 were recognized at macro levels only, and 15 were recognized at micro levels only.

The most easily identified cases of RIS are those where microearthquakes have shown good correlation with the filling history and/or changes in water depth. However, the recognition of such a correlation requires detailed microseismicity data from local seismic networks. Because high quality microearthquake arrays are established at very few reservoirs, many cases of reservoir induced microseismicity may not have been recognized. For many of the reported cases of reservoir induced macroseismicity, there appears to have been no change in the frequency or magnitude of background seismicity (Table 2-1). However, the seismicity often is associated in space and time with the filling of the reservoir or with water level fluctuations.

The data collected on deep and/or very large reservoirs, the data on reported cases of RIS, and the assessment of the RIS cases, were combined to construct preliminary statistical models for predicting the probability of occurrence of RIS. These statistical studies have indicated an association between maximum water depth and the occurrence of reservoir induced seismicity. A less discriminating attribute for distinguishing between accepted RIS and not-accepted RIS cases appears to be reservoir volume. Other attributes considered include geology of the reservoir area, regional stress regime, and faulting that has exhibited displacement during the active tectonic regime.

The models constructed from these attributes indicate the effects of certain combinations of attributes on the occurrence of RIS and illustrate the range of probabilities that can be obtained for combinations of the attributes; however, because of the relatively small number of cases of RIS and their distribution, these models are sensitive to changes in data classification.

# 3.0 THEORETICAL MODELLING OF RESERVOIR INDUCED SEISMICITY

## 3.1 INTRODUCTION

From a comparison of the time and location of reported induced seismicity (discussed in Section 2.1) with the reservoir water level, two observations can be made: 1) The seismicity often occurs during the initial reservoir filling, and 2) A strong correlation exists between the frequency of seismicity and the changes in the water level. Moreover, a delay of several days to several months is often noted between rapid water level changes and peak seismic frequency.

Several numerical techniques have been developed to compute stress levels in the rock beneath a reservoir, and these stress levels have been compared to the time and place of observed seismicity at a number of reservoirs.

Modelling of elastic halfspaces, using techniques developed by Gough and Gough (1970), Lee (1972) and Nyland and Withers (1976), have been applied to induced seismicity cases. Models that consider fluid within the rock have also been used. The equations governing the behavior of a fluid-filled elastic solid were developed by Biot (1941a), and expansion techniques have been developed by Withers (1977) and by Bell and Nur (1978).

## 3.2 ELASTIC MODELS OF RIS

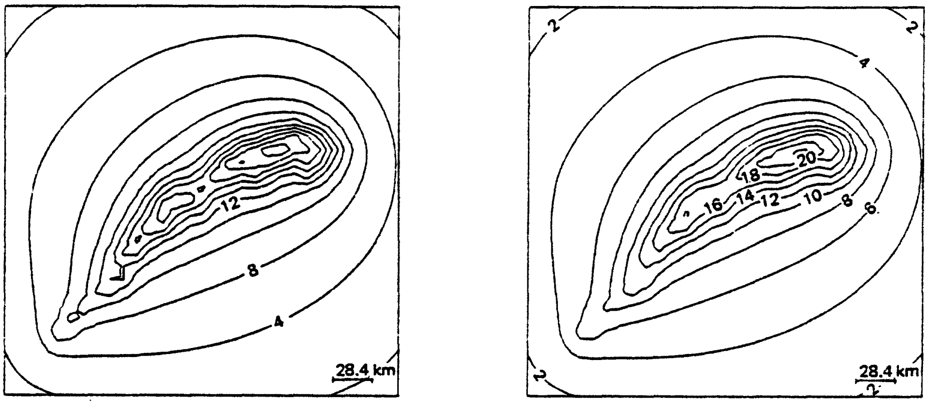
### 3.2.1 Modelling of Elastic Materials

To understand the mechanism of the seismic stress release, the magnitude of the stresses generated by the filling of the reservoir must first be calculated. This calculation of the response of a non-gravitating elastic halfspace to surface pressures is called the Boussinesq problem (Timoshenko and Goodier, 1970; Farrell, 1972).

The Boussinesq problem involves calculation of the deflection and stress matrix beneath a surface load. The Boussinesq solution was first applied to lake loading at Kariba reservoir which was approximated into 1300 vertical point forces, each representing the average pressure over a unit area (Gough and Gough, 1970 a,b). The displacement and stresses at each load point were calculated, and their contributions were summed at the point of interest. The displacement term decreases as the inverse of the distance from the surface point force and stresses decrease as the distance squared.

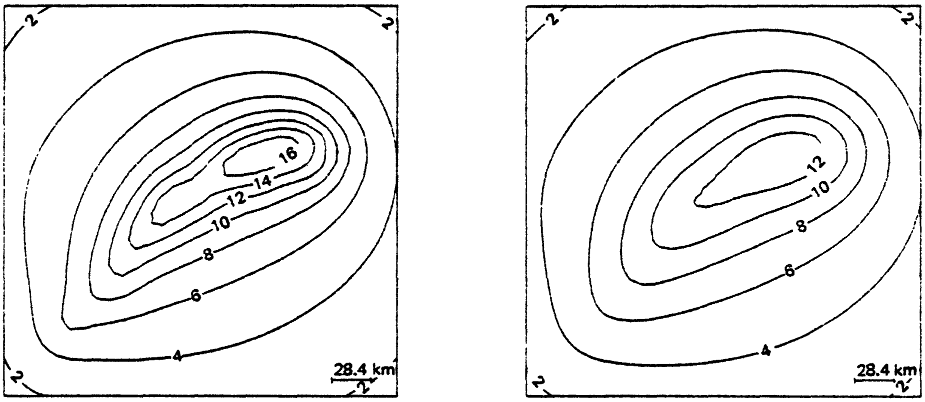
As an example, the Kariba reservoir was approximated at 80 m deep (average), 25 km wide, and 200 km long. The calculated maximum shear stress was only 2.1 bars under the deepest part of the lake. The predicted deflection at the surface was a maximum of 23 cm, which is in good agreement with the observed deflection along a nearby road. This deflection extends over a larger area and decreases with depth as seen in Figures 3-1 and 3-2. This same technique was applied to the Oroville Reservoir by Beck (1976), who found the largest shear stress was 3.4 bars, again under the deepest part of the lake. Because Oroville is about twice as deep as Kariba, this larger stress is expected.

Another technique for the solution of the Boussinesq problem involves a Fourier-Bessel expansion of the elasticity equations in cylindrical coordinates (Lee, 1972). A lake is approximated by a pattern of elemental loads, each shaped as a section of an annulus. The advantage of this method is the solution of the displacements and the variance of elastic parameters with depth.



VERTICAL DISPLACEMENT (cm)
Depth = 0, with sigma = 0.27
Young = 0.85 MBAR
2 cm contour interval

VERTICAL DISPLACEMENT (cm)
Depth = 3 km, with sigma = 0.27
Young = 0.85 MBAR



VERTICAL DISPLACEMENT (cm)
Depth = 13 km, with sigma = 0.27
Young = 0.85 MBAR

VERTICAL DISPLACEMENT (cm)
Depth = 30 km, with sigma = 0.27
Young = 0.85 MBAR

Source: Withers (1977)

VERTICAL DEFLECTIONS AT SEVERAL DEPTHS BELOW LAKE KARIBA, BASED ON ELASTIC HALFSPACE MODEL

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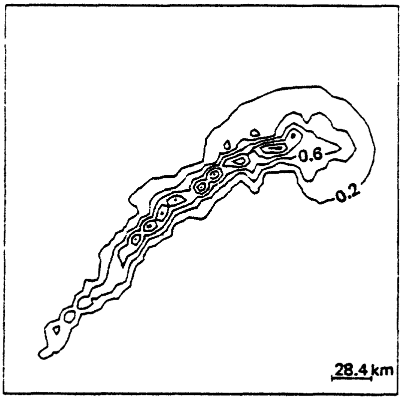
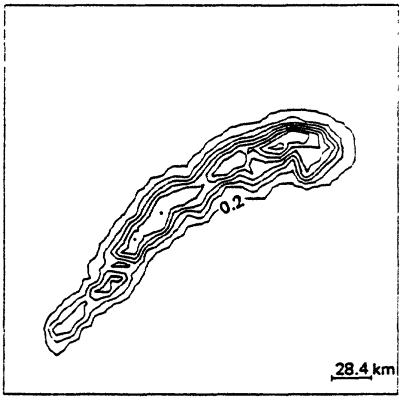
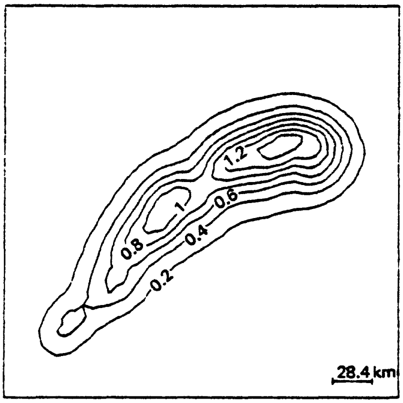
Figure 3-1



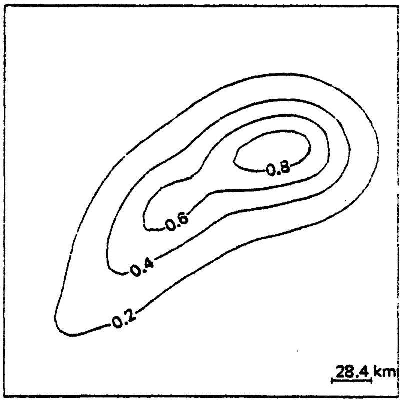
MAXIMUM SHEAR STRESS (bars)
Depth = 0, with sigma = 0.27
Young = 0.85 MBAR
0.2 Bar contour interval



MAXIMUM SHEAR STRESS (bars)
Depth = 3 km, with sigma = 0.27
Young = 0.85 MBAR
0.2 Bar contour interval



MAXIMUM SHEAR STRESS (bars)
Depth = 13 km, with sigma = 0.27
Young = 0.85 MBAR



MAXIMUM SHEAR STRESS (bars)
Depth = 30 km, with sigma = 0.27
Young = 0.85 MBAR

Source: Withers (1977)

MAXIMUM SHEAR STRESS AT SEVERAL
DEPTHS BELOW LAKE KARIBA,
BASED ON ELASTIC HALFSPACE MODEL

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Figure 3-2

The third technique for solution of the Boussinesq problem was developed by Nyland and Withers (1976) and involves a Fourier transformation. The equation of elasticity may be simplified by taking the transform of the equation: derivatives become multiplications which are a much simpler computation. The boundary effects may also be simply defined in two dimensions in the Fourier Domain. The numeric procedure involves overlaying the reservoir with a regular two-dimensional grid, usually 64 x 64, and the values at each node are defined by the reservoir depth.

The Fourier Transform technique was applied to Kariba Reservoir, and results similar to those obtained by Gough and Gough (1970a,b) were derived. The Fourier Transform technique can be expanded by a matrix technique to model a layered halfspace beneath the reservoir (Withers and Nyland, 1976).

As demonstrated in elastic modelling demonstrated that even the very deepest reservoirs could not create more than a few bars of maximum shear stress in rock located beneath the reservoir. This amount of shear stress is two orders of magnitude too small to initiate new fractures in intact rock and is about an order of magnitude less than required to initiate movement along preexisting fractures. For this reason, the small, induced elastic forces associated with reservoir impoundment can act only as triggering forces. The material beneath the reservoir must already be fractured and prestressed by existing forces to a point very near failure. The additional load applied by the filling of the reservoir would appear to bring the rock to failure which is observed as a seismic event. Thus, cases of reported seismicity should occur in areas of high stress levels and require zones of weakness, such as active faulting, to exist close to the reservoir. The results of the modelling also suggest that because of the limited influence, the seismicity must occur "near" the reservoir. The modelling indicates a spatial and temporal association with the reservoir, given the right conditions of a high stress level and existing faulting. Therefore, an earthquake which would have occurred later in the normal geologic sequence may be prematurely triggered by the filling of a reservoir.

## 3.3 MODELS OF RESERVOIR INDUCED STRESSES IN ELASTIC FLUID-FILLED MATERIALS

The elastic halfspace modelling has a basic disadvantage: it has no mechanism for exploring 1) why a short delay of a few days to a few months occurs between water level fluctuations and the detected seismicity, and 2) why the seismicity does not always occur immediately after initial filling. The inability of the modelling to explain time effects indicates that other triggering mechanisms may be effective and that further research in effective stress modelling is necessary.

The effective stress can be expressed as an algebraic sum of the acting elastic stresses plus the pore fluid pressure in the rock. Such fluid may be assumed to already exist in the rock or may enter the rock by diffusion from the bottom of the reservoir, thus raising the water table. Whichever is the case, the fluid has the ability to transfer larger stresses, of about 10 bars for 100-m-deep reservoirs, to significant depths in the rock.

### 3.3.1 Application of Biot Models of Elastic Solids Containing Fluids

Biot (1941a) developed basic equations governing the behavior of elastic solids containing fluids. The theory was conceived for the study of consolidation of foundations in clay and sandy material but is sufficiently general to be applied to rock located beneath a reservoir. As Rice and Cleary (1976) suggest, the recently popular theory of mixtures of interacting continuum has little advantage over the classical theory of Biot under conditions where local equilibrium of the pore fluid may be assumed.

For Biot's (1941a) theory, the equilibrium equations are:

$$G\left[\nabla^2\vec{U} + (2\eta - 1)\ \nabla\nabla \cdot \vec{U}\right] - \alpha\nabla p = 0 \tag{1}$$

$$k\nabla^2 p = \alpha\ \frac{\partial\nabla \cdot \vec{U}}{\partial t} + \frac{1}{Q}\ \frac{\partial p}{\partial t} \tag{2}$$

where $\vec{U}$ is the displacement of the solid matrix,
$p$ is the pore pressure,
$G$ and $\eta$ is the elastic constants of the matrix expressed in terms of Young's Modulus $Y$, and is Poisson's Ratio $\nu$,

$$G = \frac{Y}{2(1 + \nu)} \qquad \eta = \frac{1 - \nu}{1 - 2\nu}$$

Modelling with this theory has been extensively performed by Withers (1977) using Fourier transforms; the results of this modelling has been applied to reported cases of reservoir induced seismicity. In the elastic model solutions of the Boussinesq problem, the only rock parameters required were $G$ and $\eta$, which were generally estimated from local rock material. For the Biot approach, three fluid parameters are also required, $k$, $\alpha$ and $Q$. $k$ represents the permeability of the matrix and, in the development of the mathematics, appears only to act as a linear time-scaling constant. Thus, if the permeability is doubled, the same result is obtained in exactly half the time. $\alpha$ may be interpreted as the ratio of the volume of fluid alone to the volume of the solid, if the latter is allowed to compress while allowing the fluid to escape. $1/Q$ is a measure of the amount of fluid that can be forced into the solid under pressure while the volume is kept constant.

The constants $Q$ and $\alpha$ depend on the flow regime within channels in the rock and are the most difficult parameters for which reliable values can be obtained. Jaeger and Cook (1976) show that $\alpha = 1$ and $Q = \infty$ are acceptable values for rock in laboratory conditions. This assumes that the rock is saturated and that the compressibility of water is much less than that of rock. Computations made with these parameters, using a boundary condition that the fluid pressure is continuous across the surface interface, led to results in which final equilibrium is reached instantaneously and no time lags exist. These results have not been observed during loading and must be due to a poor selection of the parameters $Q$ and $\infty$.

The parameter $\alpha$ relates to the rock saturation. It is reasonable to assume that rocks are relatively saturated so that $\alpha$ is between 0.9 and 1.0. For soils, the value of $\alpha$ may be about 0.7. The smaller the value of $\alpha$, the longer it takes for equilibrium to be established; however, if too small a value is selected, the phenomenon called the Mandel-Cryer effect may be observed. The Mandel-Cryer effect (Schiffman and others, 1969) exists when an anomalously high pressure lobe is observed at depth beneath the surface load. These pressures may exceed the applied load.

The other parameter, $Q$, is specified in terms of initial (undrained) and final (drained) compressibilities. In laboratory samples, the final compressive state is almost entirely due to water volume changes, and $Q$ is necessarily infinity. If the value of $Q$ is lowered from infinity, realistic time delays may be achieved with Q about 10 times larger than Young's modulus. After the load has been applied, very little post filling consolidation is observed for this example. The literature on Q and $\alpha$ for rocks is limited. The results of compressive tests on drained and undrained black shales indicate that Q is of the same order of magnitude as the drained Young's modulus.

To solve the Biot equations, certain conditions must be met at the surface. Several conditions are possible for the water boundary equation. For one, the flow through the surface may be specified; however, this is an inadequate solution since the flow is so difficult to verify. The most obvious choice for a boundary condition is defining the water pressure at the surface. This selection may be variable over length scales of tens of kilometers; however, under ideal conditions, water pressure changes can be monitored at the surface and the modelling can be verified.

Two extreme boundary conditions can be selected. If the bottom of the reservoir is sealed and no connection exists between the reservoir and the ground water, then the surface water pressure is zero. This is called zero coupling with the ground water. Full coupling exists where the ground water surface value equals that of the reservoir. In normal soil situations, full coupling may be the case; however, leakage would be a major problem and reservoirs are usually impounded on more impermeable bases. For this reason, the coupling should lie between 0 and 1; in the modelling studies to date, 0.25 seems to indicate a good compromise. Since the fluid connection of the reservoir and ground water is via channels and fissures that narrow with depth, it is feasible to explain the reduced coupling. This reduction of pressure by flow in confined channels is called the Bernouilli effect. It is also possible that variable hydrologic parameters at shallow depths, incomplete fluid coupling, and capillary narrowing all affect the flow concurrently.

Biot equations (1) and (2) may be solved using the lake geometry and depth as a source function, and G, $\eta$, k, Q, $\alpha$, and coupling as variables. The values of G, $\eta$, and k can be reasonably estimated from the rock type and local hydrology, but considerable uncertainty exists for the variables Q, $\alpha$, and coupling. It is in this area that major research is presently directed.

Bell and Nur (1978) have reexamined the Biot equations using an elastic and hydrologic parameters developed by Rice and Cleary (1976). The field equations they derived are similar to equations (1) and (2)

$$2G\varepsilon_{ij} = \sigma_{ij} - \frac{\nu}{1 + \nu}\,\sigma_{kk}\delta_{ij} + \frac{3(\nu_\mu - \nu)}{B(1 + \nu)(1 + \nu_\mu)}\,p\delta_{ij} \qquad (3)$$

$$\frac{\partial}{\partial x_i}\left(k\,\frac{\partial p}{\partial x_i}\right) = \frac{3(\nu_\mu - \nu)}{2GB(1 + \nu)(1 + \nu_\mu)}\,\frac{\partial}{\partial t}\left(\sigma_{kk} + \frac{3}{B}\,p\right) \qquad (4)$$

where $\nu_\mu$ is the undrained (no change of mass) Poisson's ratio having limiting values $1/2 \geq \nu_\mu \geq \nu$. The upper limit is reached for separately incompressible constituents, and the lower bound is achieved where the pore fluid is highly compressible. The constant B is expressed as a ratio of bulk modulii. B is typically 1 for water-saturated soils but can be substantially less for rocks, the constituents of which are not effectively incompressible. The constants $\nu_\mu$ and B can be derived from a single undrained test in which the Poisson effect and pore pressures are measured.

$$\Delta p = -\ B\ \frac{\Delta\sigma_{kk}}{3} \tag{5}$$

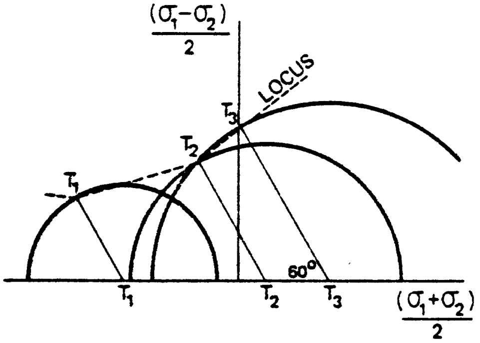
$$B = \frac{1/K - 1/K_s'}{\nu_0/K_f + 1/K - 1/K_s' - \nu_0/K_s''} \tag{6}$$

$$2G\Delta\varepsilon_{ij} \equiv \Delta\sigma_{ij} - \frac{\nu_\mu}{1 + \nu_\mu}\ \Delta\sigma_{kk}\delta_{ij} \tag{7}$$

Rice and Cleary (1976) present typical values of the variables B and $\nu_\mu$ derived from elastic and hydraulic testing. These values indicate B is 0.8% for Ruhr sandstone, 0.85 for Westerly granite, and 0.51 for Tennessee marble. The corresponding values of $\nu_\mu$ are 0.31, 0.34 and 0.27, respectively. These parameters were not directly measured in the single undrained test and probably have considerable variation.

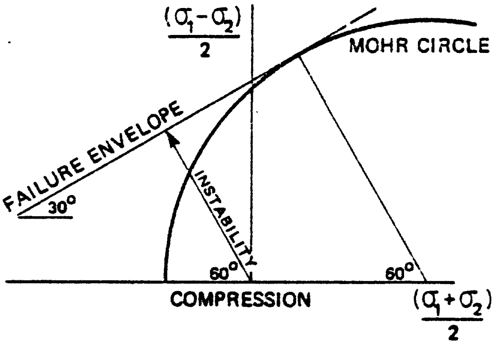
## 3.4 PREDICTION OF FAILURE

The Mohr failure criteria require that the sum and difference of the principal stresses be specified everywhere. Because in modelling these amounts vary in three dimensions as well as in time, they are difficult to represent. For this reason, several abbreviated representations have been used. One of these is the plot of the locus of a point on the Mohr circle. The representation is shown on Figure 3-3a for several times, and the Mohr circle can be reconstructed from the locus. The small anomalous stresses computed can be added to the existing stresses without using matrix rotation to obtain the principal stresses. Thus, as shown in Figure 3-3b, the initial undisturbed situation is at the origin, and movement of the



Method of determining the locus of the Mohr circle with time.

(a)



The instability is shown as a projection of the Mohr circle onto the center of the initial prestressed condition.

(b)

EXAMPLE RESERVOIR: DEVELOPMENT OF MOHR CIRCLE LOCI

| | |
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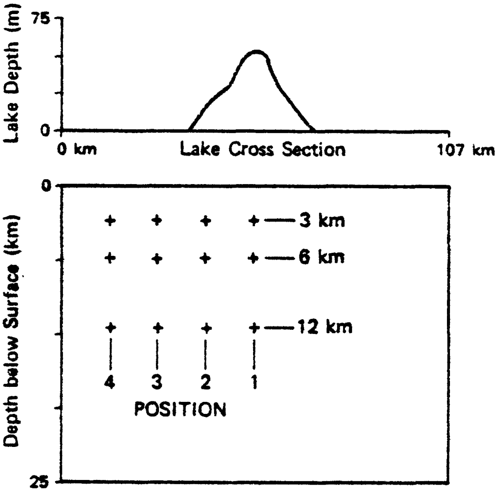
Mohr locus to the upper left quadrant is in the direction of the failure envelope. Seismicity may occur if the rock is close to failure, and the locus crosses an unknown prestressed failure envelope.

Motion into this upper left quadrant has been identified as increased "instability," as shown by Figure 3-3b. Unfortunately, the amount of instability required to activate an earthquake in a particular area is not known. Various estimates of this value for particular faults can be made from the computed stress drops during large earthquakes. These are typically 10 to 100 bars but can be as low as 1 bar in some instances.

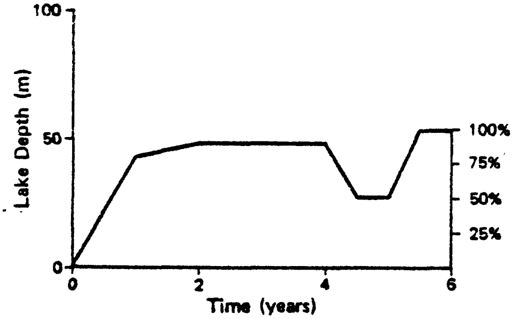
To illustrate the typical analysis, a two dimensional load will be represented here. modulus of 0.85 megabars, Poisson's ratio of 0.27, permeability of 2.0 millidarcy, $Q = \infty$, $\alpha = 1$, and a coupling of 0.25 were selected for this example. Because the model reservoir was approximately 30 km across, loci were examined at the depths of 3 km, 6 km and 12 km, using the offsets 1, 2, 3, and 4, as shown on Figure 3-4a. Position 1 is directly below the reservoir. Position 4 is offset approximately 40 km from the center. The water depth was 5 m, and the selected filling, shown in Figure 3-4b, is typical of many reservoirs.

The Mohr loci shown on Figure 3-5 are for normal faulting in which the maximum principal stress is vertical. For the selected boundary conditions, the largest instability after 1 year occurs at 6 km directly below the reservoir. The instability is approximately 0.12 MPa above the tectonic level and, depending on the sensitivity of the area, may trigger an earthquake. At 2 years, the maximum instability has moved to 12 km below the lake. This position is more unstable at 2 years than at 1 year and is even more unstable than the



Positions for which loci of Mohr circle were plotted in Figure 3-3. Position 1 is directly beneath reservoir and position 4 is offset 40 km from beneath the center.

(a)



Assumed Reservoir Filling History.

(b)

EXAMPLE RESERVOIR: POSITIONS
BELOW LAKE AND RESERVOIR
FILLING HISTORY

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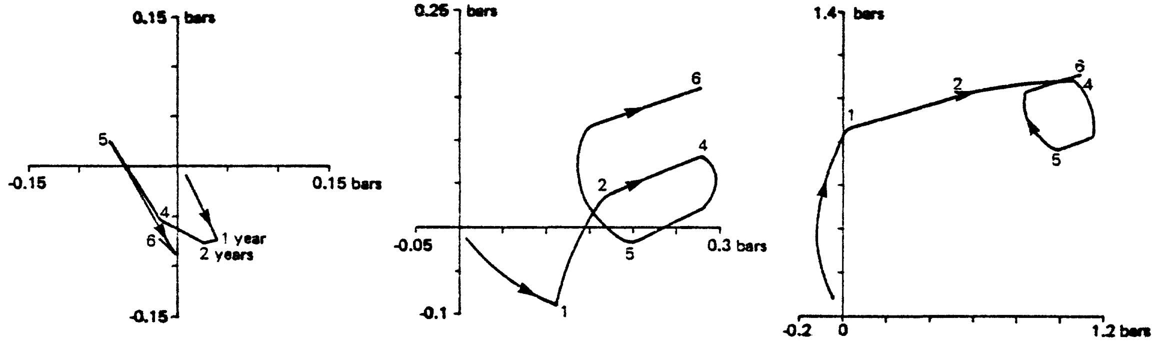
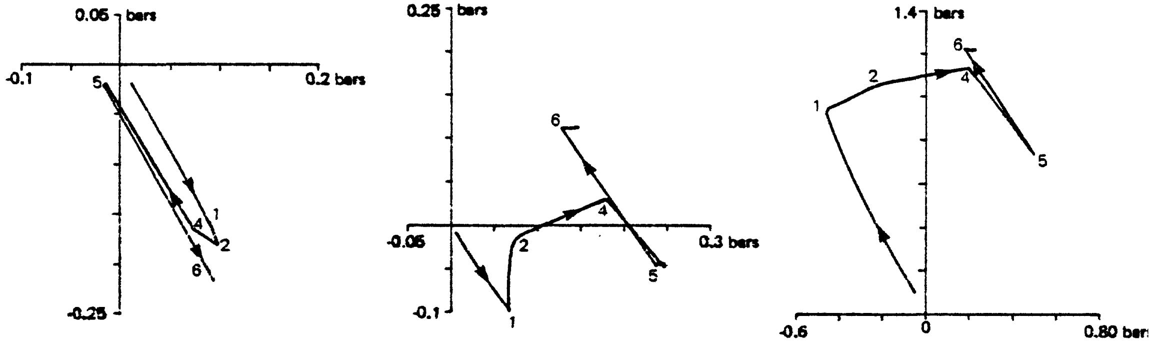
Figure 3-4



DEPTH—3 km
POSITION 3

DEPTH—3 km
POSITION 2

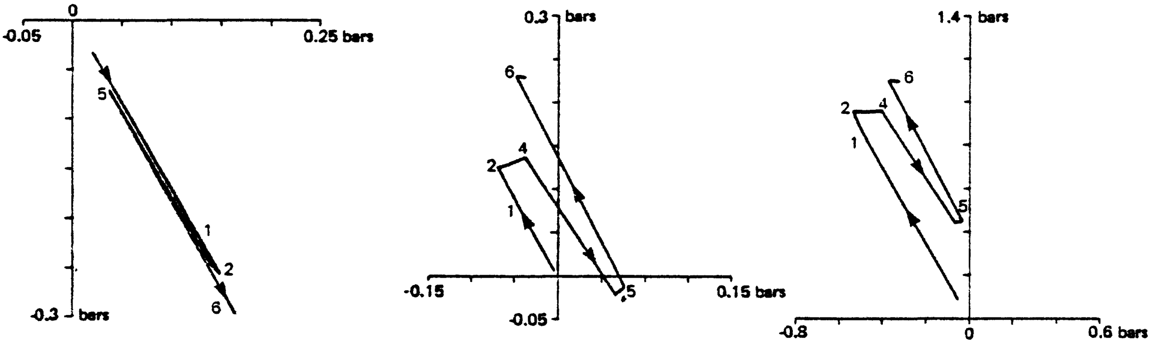
DEPTH—3 km
POSITION 1



DEPTH—6 km
POSITION 3

DEPTH—6 km
POSITION 2

DEPTH—6 km
POSITION 1



DEPTH—12 km
POSITION 3

DEPTH—12 km
POSITION 2

DEPTH—12 km
POSITION 1

Source: Withers (1977)

NOTE:

See Figure 3-4 for filling history and diagram of position locations.

Scale changes according to the figure.

Time in years shown on locus.

Position of maximum instability varies with time. At one year, maximum instability occurs at position 1, depth 6 km. At two years, it occurs at position 1, depth 12 km. After 5.5 years, maximum instability occurs at position 1, depth 12 km.

LOCI OF THE MOHR CIRCLE IN A
NORMAL FAULTING ENVIRONMENT

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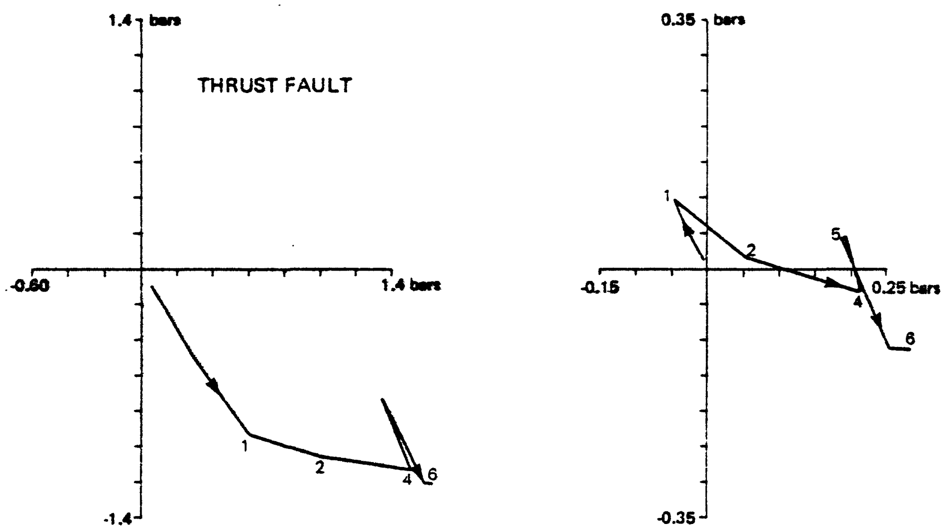
Figure 3-5

position 6 km beneath the reservoir. Thus, if an earthquake had not occurred at 6 km earlier, it may still be triggered at 12 km 2 years after initiating filling. At positions 2, 3, and 4, the stresses are much lower. Thus, in this instance, the initial filling would have created the largest anomalous stresses. The reservoir induced seismicity at both Vayont and Kremasta are typical of failure during the initial filling.

The second part of the filling history of this example (Figure 3-4b) was associated with an unload and refill cycle. This history was chosen since it is similar to the filling of Lake Oroville, California, where the main shock (normal faulting) occurred just as the refill was completed. At the 3-km and 6-km depths beneath the reservoir (Figure 3-5), the stresses at 5.5 years (completion of refilling) are always less than those earlier in the filling. However, at 12 km the instability is greatest at 5.5 years. In fact, this is the greatest instability produced at any location during the entire loading cycle. Thus, if an earthquake had not been triggered by the lower stress levels earlier, then one would most likely have occurred below the reservoir at 5.5 years.

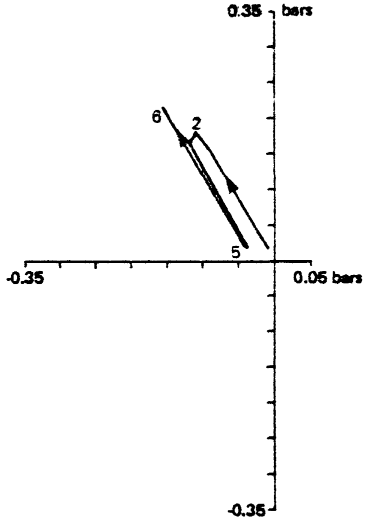
It is important to examine the stresses at 12 km at position 2. Although the stress levels are smaller there than beneath the reservoir, a marked increase in instability occurs at 5.5 years at the edge of the reservoir. If a local zone of weakness exists, it is possible, under these conditions, for the seismicity to be offset from the center of the reservoir during the refill cycle.

The examination of the loci in a thrust environment (shown on Figure 3-6) leads to different conclusions. Here the initial filling stabilizes the area beneath the lake. Offset from the reservoir, the instability increases during the initial filling, decreases during the unload, and increases again



DEPTH—6 km
POSITION 1

DEPTH—6 km
POSITION 2



DEPTH—6 km
POSITION 3

Source: Withers (1977)

NOTE:

Scale changes according to the figure.
Time in years shown on locus.

Maximum instability occurs to the side of the lake.

INSTABILITY AT TWO-DIMENSIONAL LAKE IN THRUST ENVIRONMENT

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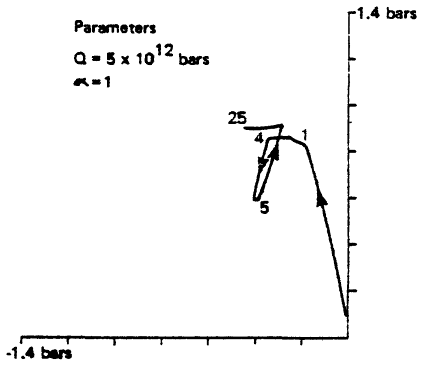
Figure 3-6

during the refilling. The stress levels are smaller than those for the normal faulting case, but they indicate that the triggered seismicity would be offset from the reservoir.

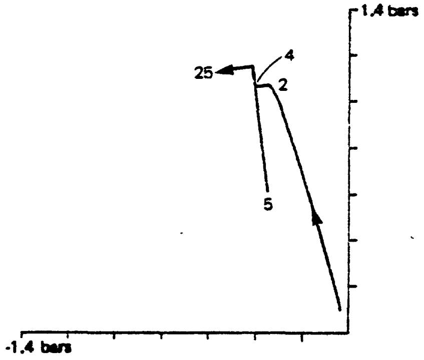
## 3.5 ADDITIONAL OBSERVATIONS

Obviously no model is better than the parameters used and the uncertainty in choosing values for $\alpha$, Q, and the coupling. Figure 3-7, which illustrates the effect that Q has on the results for normal faulting, should be compared with Figure 3-5. Again, the seismic event would have occurred below the reservoir, but the time of the event is now less dependent on the drawdown-refill cycle. In this example, the fluid pressure is increasing with time as the pressure diffuses to depth, and this is reflected in the movement of the Mohr locus to the left. Instability increases to a steady state value or until the local conditions for failure are exceeded. Further studies should emphasize more constraint of the fluid properties of rock over large distances. Strike-slip faulting has not been modelled due to the numeric expense and representation difficulties associated with three dimensional modelling.

Bell and Nur (1978) have examined the effect of a zone of permeable material dipping beneath the reservoir. This zone can considerably alter the flow pattern. Figure 3-8 shows induced pore pressure changes plotted as a function of a scaled time unit. The permeability of the fault zone in this figure is 100 times that of the surrounding rock. The strength changes are also strongly influenced by the introduction of a permeable zone. Figure 3-9 represents the strength changes for thrust, normal, and vertical strike-slip faulting for several times. A negative sign in this figure represents weakening of the rock, and a positive sign indicates strengthening.



DEPTH—3 km
POSITION 1



DEPTH—6 km
POSITION 1

Source: Withers (1977)

Time (in years) shown on locus.

Q was reduced, as compared to Figure 3-5, to allow for diffusion to occur. Diffusion takes place with full pressure coupling at the surface.

INSTABILITY IN AN AREA
OF NORMAL FAULTING

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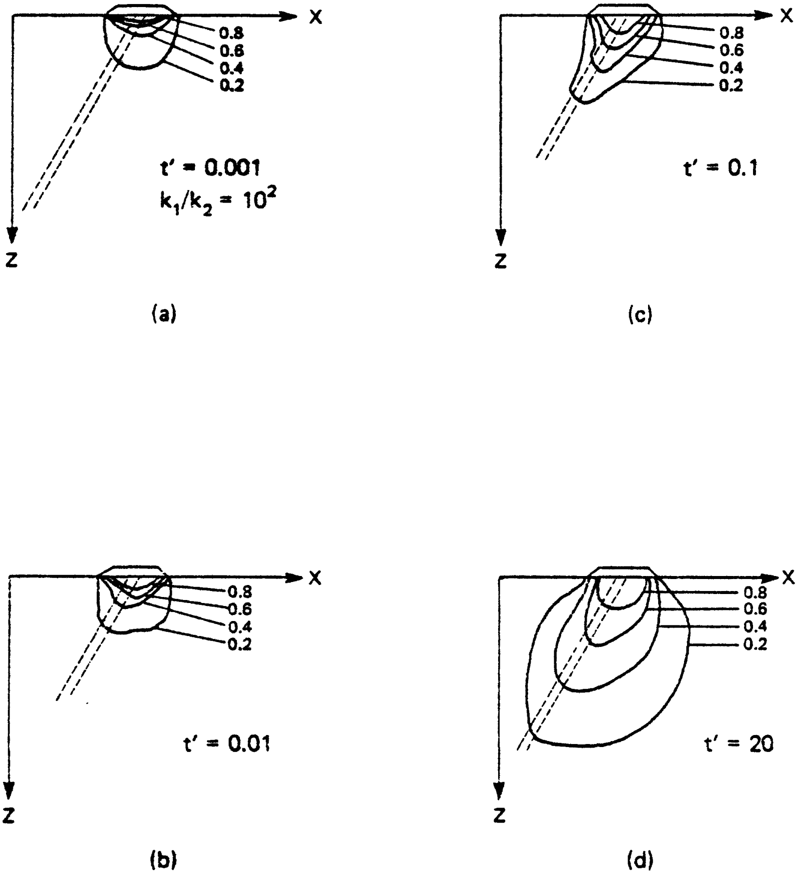
Figure 3–7

# PORE PRESSURE



EXPLANATION:

| | |
|---|---|
| $k_1$ | Permeability within fault zone |
| $k_2$ | Permeability of rock |
| ⌒ | Hypothetical reservoir |
| t' | Dimensionless (relative) time |
| // | Permeability fault zone |
| | Strength changes in fractions;<br>-0.1=10% weakening of rock strength |

Source: Bell and Nur (1978))

NOTE:
The permeability of the fault zone is 100 times that of the surrounding halfspace ($k_1/k_2=10^2$)

INDUCED CHANGE IN PORE PRESSURE FOR VARIOUS TIMES, BASED ON HALFSPACE MODEL WITH PERMEABLE FAULT ZONE

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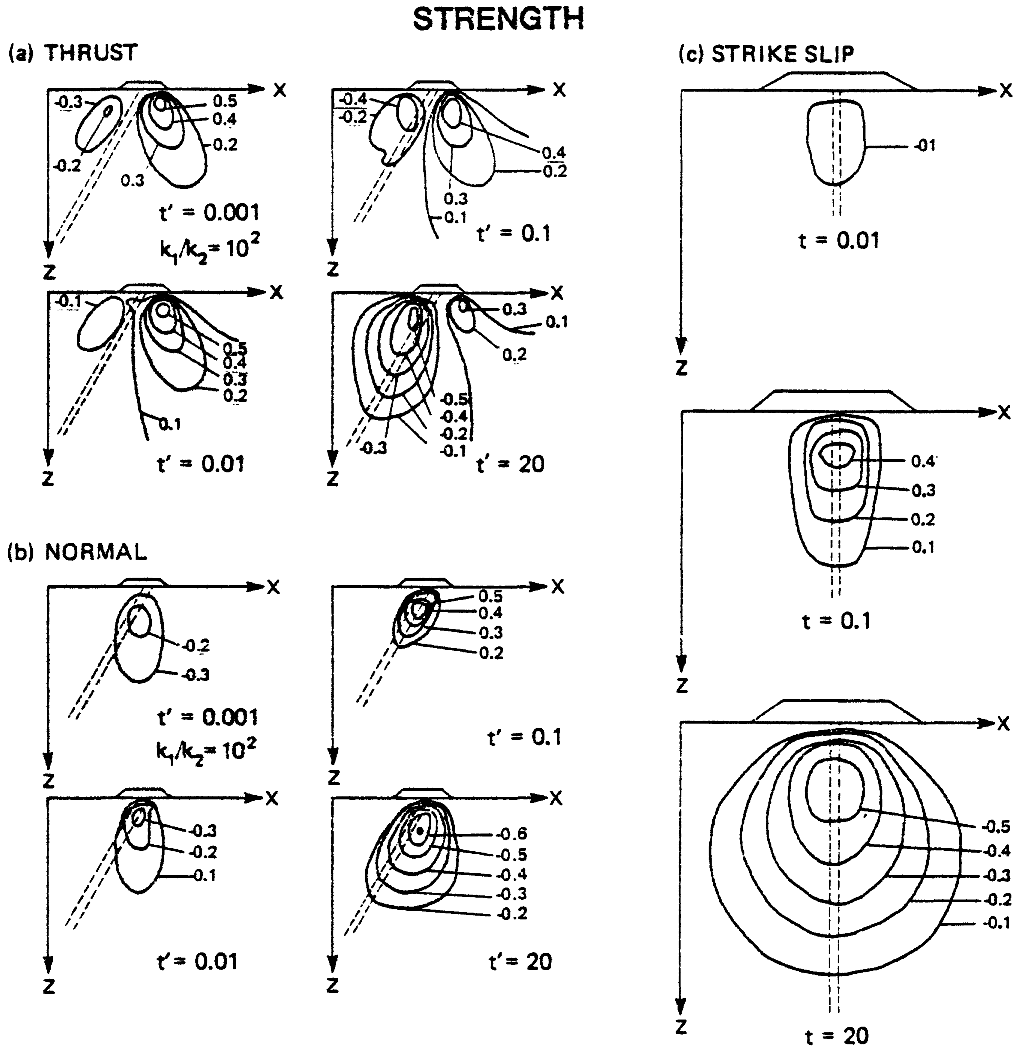
Figure 3-8



**EXPLANATION:**

| | |
|---|---|
| $k_1$ | Permeability within fault zone |
| $k_2$ | Permeability of rock |
| ⌒ | Hypothetical reservoir |
| t′ | Dimensionless (relative) time |
| // | Permeability fault zone |
| | Strength changes in fractions;<br>-0.1=10% weakening of rock strength |

**NOTE:**

Two-dimensional (x-z) representation of strength changes below hypothetical reservoir having a thrust, normal, or strike-slip fault beneath reservoir. The fault zone permeability is 100 times that of the surrounding region ($k_1/k_2=10^2$). A negative sign indicates weakening, and a positive sign indicates strengthening.

Source: Bell and Nur (1978)

STRENGTH CHANGES AS A FUNCTION OF TIME, BASED ON HALFSPACE MODEL WITH PERMEABLE FAULT ZONE

| | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 3-9<br>Page 101 |

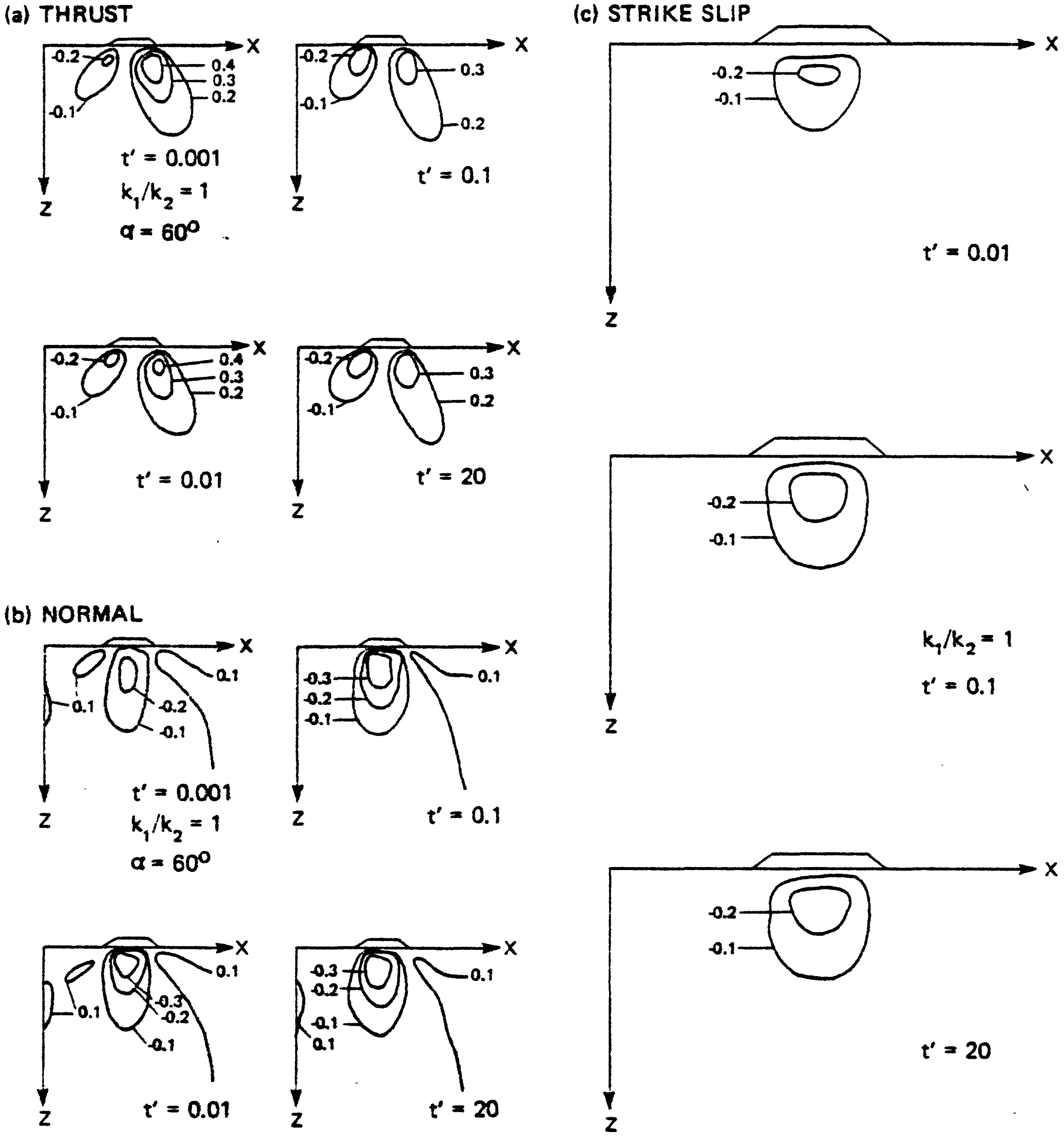
Upon comparison of Figure 3-10, where the permeable zone is absent, with Figure 3-9, several conclusions can be made: For thrust faulting, the strength patterns with and without the permeable zone are similar. However, as time increases, the effect of the fault zone greatly weakens the strength in its vicinity. The final steady state value of the strength change for thrust faulting about doubles after the introduction of the permeable zone and influences a considerably larger area when the faulting is present. For the normal faulting case, the steady state strength change also doubles and influences a larger area.

Modelling with a permeable fault zone provides a significant alternate mechanism for explaining how large, effective stresses penetrate to great depths. From Figure 3-9, the weakening in the direction of shear for normal faulting achieves a reduction of strength by up to 70 percent of the maximum applied water load. For strike-slip faulting, the reduction of strength is as much as 55 percent of the applied water load. The thrust case also contains significant strengthening zones, whereas normal and strike slip cases do not.

## 3.6 CONCLUSIONS

Theoretical modelling has made great advances in explaining the mechanism of induced seismicity beneath reservoirs. The elastic halfspace models have been used successfully to predict ground deflection and would indicate that only very small stresses could be generated by reservoir filling. The fluid models, based on Biot's consolidation theory, allowed for much larger triggering stresses to be generated at depth by either pressure build-ups or by zones of low permeability. Seismicity during initial filling and observed delays in the seismicity associated with small changes in water level can be

## STRENGTH



EXPLANATION:

| | |
|---|---|
| $k_1/k_2 = 1$ | Permeability equal throughout halfspace |
| ⌒ | Hypothetical reservoir |
| t′ | Dimensionless (relative) time |
| α | Dip angle of fault |
| | Strength changes in fractions;<br>-0.1 = 10% weakening of rock strength |

NOTE:

Two-dimensional (x-z) representation of change in strength below hypothetical reservoir where tectonic stresses favor development of (a) thrust, (b) normal, or (c) strike-slip faults. A negative sign indicates weakening, and a positive sign indicates strengthening.

Source: Bell and Nur (1978)

CHANGES IN STRENGTH FOR SEVERAL TIMES, BASED ON HALFSPACE MODEL WITH SUPERIMPOSED TECTONIC STRESSES

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Figure 3-10

explained by the fluid-filled models. These models also explain the occurrence of seismicity away from the center of the reservoir.

A number of uncertainties still exist in the modelling which limit its applicability. These limitations are in general due to a lack of knowledge of large-scale elastic and hydrologic behavior of the rocks. The level of saturation and the fluid/rock system compressibility behavior over large dimensions are still major uncertainties. The mechanism of coupling between the ground water and the reservoir is also not understood and yet significantly alters the results of theoretical models. Unfortunately permeability, which can be measured from well tests, is not a fundamental parameter of the model, as it only influences the time-scale of the modelling.

If more were known of the deformation behavior of water-saturated rock systems, then modelling might be used to better understand the observed seismicity at a number of reservoirs having reported induced seismicity. From such research, modelling may then be applied to risk assessments of proposed reservoirs.

# 4.0 STUDIES OF FAULTING AT SELECTED RESERVOIRS

## 4.1 INTRODUCTION AND CONCLUSIONS

Models of the stresses created by the filling of reservoirs suggest that the stresses are not sufficient to initiate new fractures and that the reservoir impoundment must trigger the release of stress along pre-stressed faults (Section 3). This implies that displacements resulting from reservoir induced seismic events on such pre-stressed, tectonically active faults must have occurred as a result of stresses created by the present or active tectonic stress regime. Since reservoir induced earthquakes are shallow, having focal depths no greater than 10 to 15 km, induced earthquakes of moderate magnitudes along these pre-stressed (active) faults might be the result of fault rupture that has extended to the surface.

Packer and others (1977) list 11 reservoirs with accepted or questionable cases of reservoir induced seismicity that have maximum magnitude earthquakes of 5.0 or greater (Table 4-1). To evaluate if faults that might have been influenced by filling of these reservoirs are active (had displacement in the present tectonic stress regime), several of these reservoirs were selected for field reconnaissance studies. Data available from the literature indicate the presence of active faults within the influence of the reservoir at two of these reservoirs, Xinfengjiang and Oroville. No conclusive published evidence of active faults near the remaining nine reservoirs was available, although studies by Snow (personal communication) suggest that active faults are present at Koyna, Kremasta, and Kariba. Of these, Koyna and Kremasta were selected for field reconnaissance to confirm and collect additional data on the possible active faulting near these reservoirs. Kariba was not selected because of the logistical

## TABLE 4-1
## RESERVOIR INDUCED SEISMIC EVENTS WITH MAXIMUM MAGNITUDE OF 5 OR GREATER

| | Packer & Others, 1977 | | This Study | |
|---|---|---|---|---|
| | Magnitude[a] | Active Faulting[b] | Magnitude | Active Faulting |
| Benmore | 5.0 | probable | 5.0 | yes[c] |
| Eucumbene | 5.0 | unknown | 5.0 | yes[c] |
| Hoover (Lake Mead) | 5.0 | probable | 5.0 | yes[c] |
| Xinfengjiang | 6.1 | yes | 6.0 | yes |
| Kariba | 5.8 | probable | 6.25 | probable |
| Koyna | 6.5 | probable | 6.5 | yes[c] |
| Marathon | >5 | probable | 5.75 | probable |
| Oroville | 5.7 | yes | 5.7 | yes |
| Kremasta | 6.3 | probable | 6.3 | yes[c] |
| Kastraki | 6.3 | probable | 4.6 | yes[c] |
| San Luis | 5.0 | unknown | not RIS | -- |
| Coyote Valley (Lake Mendocino) | (reservoir not included) | | 5.3 | yes |

---

[a] Accepted and questionable cases of RIS

[b] Faults having displacement in the present tectonic stress regime

[c] Field reconnaissance studies

difficulties of conducting geologic reconnaissance in the Zambia and Zimbabwe-Rhodesia border area. No information was known about faulting around the remaining reservoirs, and several were selected for field reconnaissance.

Of these remaining reservoirs with maximum magnitude earthquakes of 5 or greater, Hoover, Benmore, and Eucumbene reservoirs were selected on the basis of geologic setting and amount of available information. Kastraki, and Talbingo and Blowering reservoirs were selected because they are geographically adjacent to Kremasta and Eucumbene reservoirs, respectively, and could be evaluated during studies at these reservoirs. The relative scope of field reconnaissance studies at these reservoirs was less than the scope for Koyna and Kremasta.

The objectives of these reconnaissance field studies were to evaluate if active faults are present within the influence of the reservoir and to collect additional data, as available, on the reservoir and on the geology, tectonics, and seismicity of the region. These studies were of limited scope and did not evaluate or attempt to locate all active faults near each reservoir. Data from these field studies and additional data from the data collection study (Section 2) resulted in changes in the assigned maximum magnitude of induced earthquakes at several of these reservoirs (Table 4-1). In addition, an RIS event of magnitude 5 or greater was recognized at one additional reservoir, the Coyote Valley reservoir.

The results of field reconnaissance evaluation studies of active faulting at the selected reservoirs are shown on Table 4-1. Of the 11 reservoirs recognized in this study to have maximum magnitude induced earthquakes greater than or equal to 5, 9 have evidence indicating active faulting near the reservoir, and 2 probably have active faults, although no conclusive evidence is available as yet.

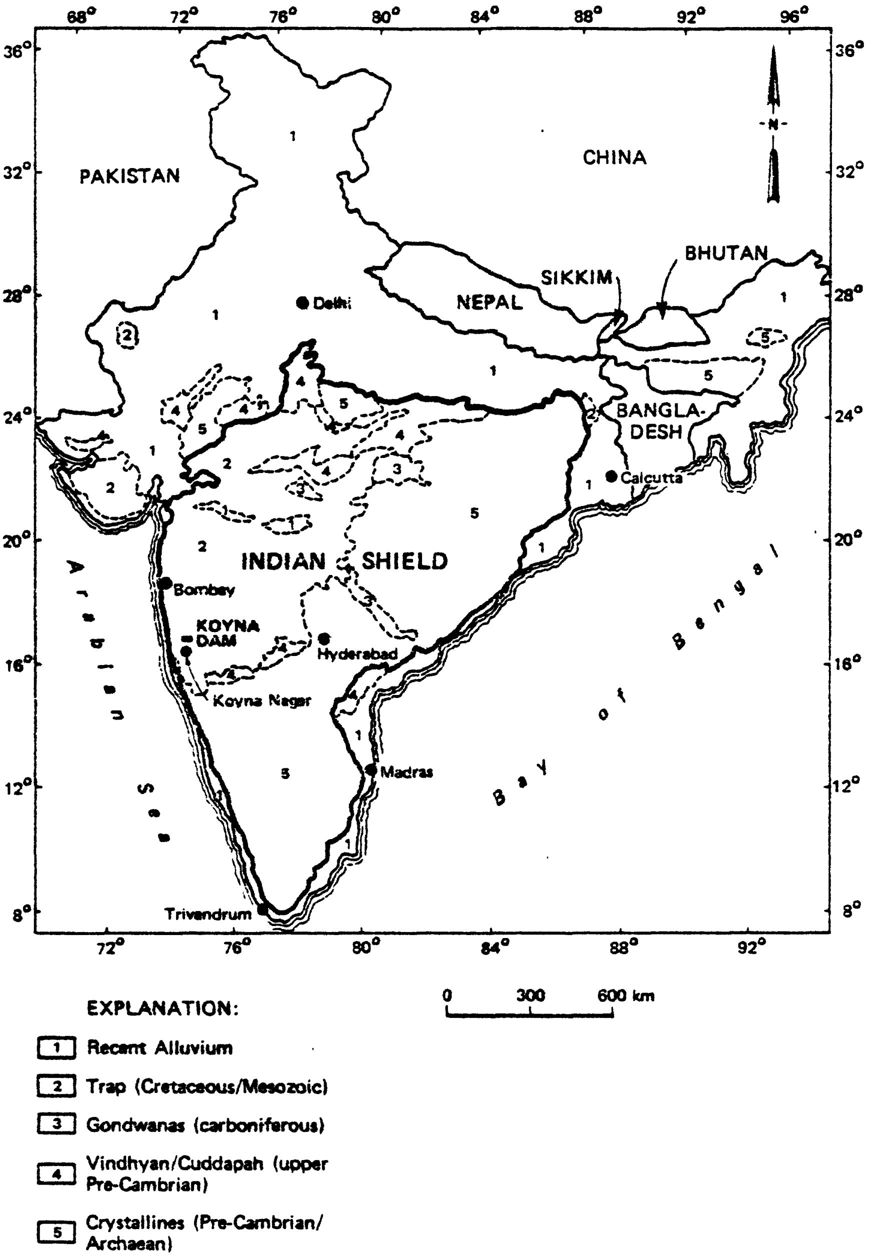
The results of these field reconnaissance studies suggest that active faults are present within the influence of all reservoirs that have triggered earthquakes with magnitudes greater than or equal to 5, and that these reservoirs did not trigger surface displacement along inactive faults.

## 4.2 KOYNA DAM REGION, INDIA

### INTRODUCTION

Koyna Dam impounds the Koyna River, forming the 100 m deep Shivaji Sagar Lake. The dam and reservoir are located in western India on the Deccan Plateau within the Indian Shield (Figure 4-1). The shield is characterized by Precambrian schist and gneiss of the Dharwar System which is overlain by flat-lying, generally unfaulted sequences of basaltic lava flows known as the Deccan Trap (Committee of Experts, 1968). Few earthquakes have been reported in the area, and the occurrence of faulting within the Deccan Plateau is reported to be virtually nonexistent, as shown on Figure 4-2. However, major fault systems are believed to be present near the margins of the plateau; these systems include the Tapi-Namada fault zone, the Cambay Graben, and the Western Ghats (Committee of Experts, 1968) (Figure 4-2). In addition, at least one north-south trending fault has been identified at the dam site (Committee of Experts, 1968; Snow, 1973).

On 10 December 1967, approximately 5 years after reservoir impoundment, an earthquake of magnitude 6.5 occurred at the Shivaji Sagar Lake, as shown on Figure 4-3 (Guha and others, 1970; Committee of Experts, 1968). A north-northeast, south-southwest trending 200-m-wide zone of cracks was reported to have occurred over a distance of approximately 3 km immediately east of the reservoir. Because of the spatial relationship of the event to the lake, numerous investigators have concluded that the occurrence of the earthquake was related to impoundment of the lake (Packer and others, 1977; Gupta and Rastogi, 1976; Rothe, 1969; Bozovic, 1974; Simpson, 1976; Gupta and others, 1972; Guha and others, 1974, Snow, 1973a,b). This earthquake is the largest reported reservoir



GENERALIZED GEOLOGIC MAP OF INDIA AND LOCATION OF KOYNA DAM

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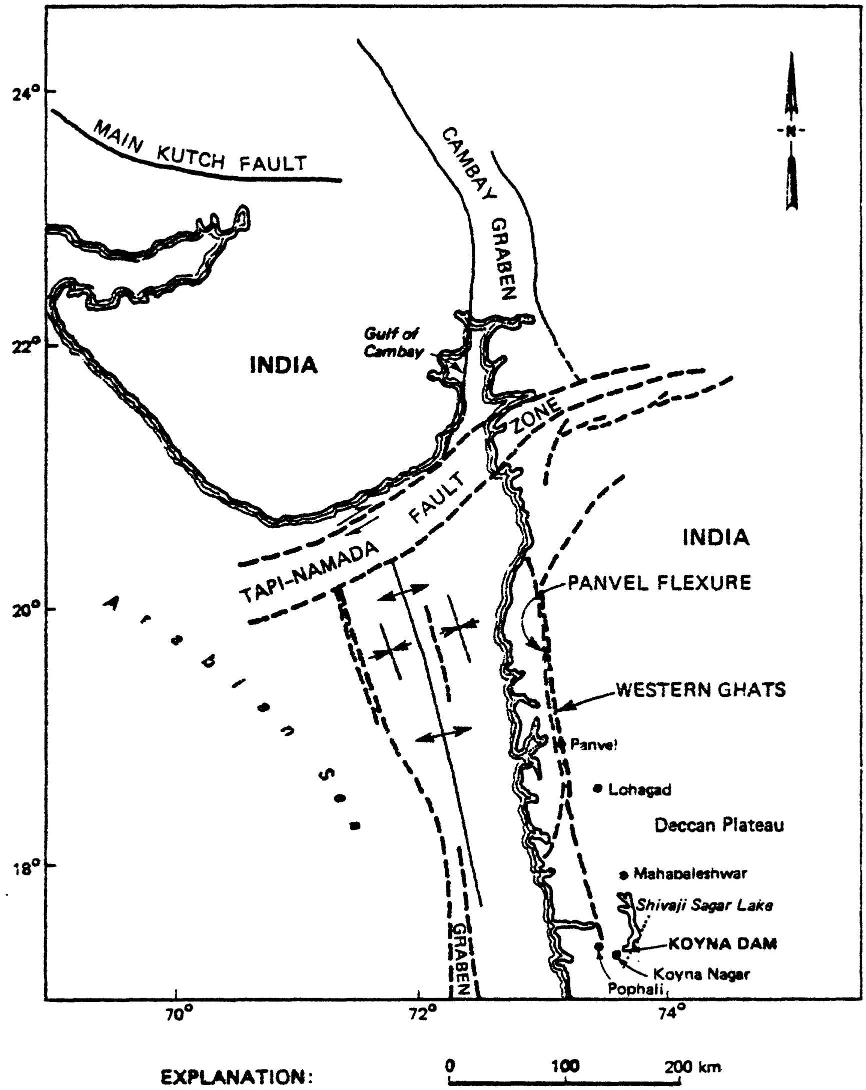
Figure 4-1



**EXPLANATION:**

- Anticline
- Syncline
- Definite Fault
- Inferred Fault
- Direction of Fault-Plane Solution

Source: Modified from Auden (1975), Kailasatin (1975), and Committee of Experts (1968).

STRUCTURAL GEOLOGY OF
WESTERN INDIA

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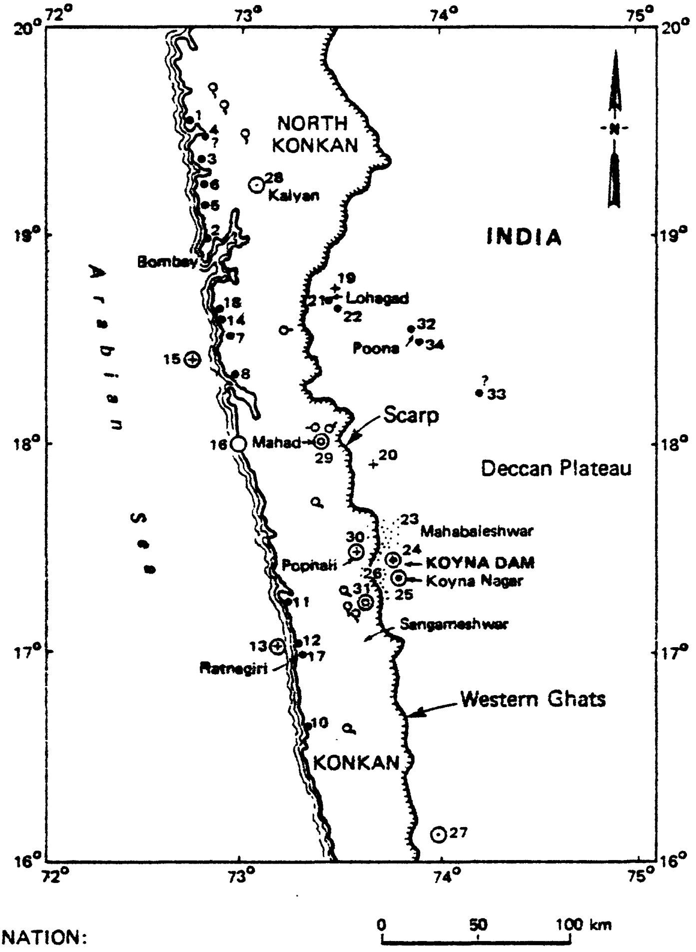
Figure 4-2



EXPLANATION:

⊙ : instrumental epicenter, M = 6.3, Int = VIII

⊕ : instrumental epicenter, M = 5-5½ Int = VII

⊕ : instrumental epicenter, M = 5, Int = VI

◎ : instrumental epicenter, M = 4.7, Int = IV-V

⊙ : instrumental epicenter, M = 4.2, Int = IV

○ : instrumental epicenter, M = ?

⁘ : swarm of epicenters, M = 3-4

+ • : macroseismic epicenters

♀ : hot springs

〰 : scarp of Western Ghats range

NOTE:
Number references earthquake to Gubin (1969).

SEISMICITY MAP OF WESTERN INDIA, FROM 1594 TO 1969

Figure 4-3

induced event in the world and is the largest reported seismic event in western India.

A study was conducted to evaluate if active faults are present within the influence of the reservoir at Koyna Dam. For the purposes of this study, a fault is defined as active if it has had displacement during that area's present stress regime. Special attention was placed on locating geologic and linear features that potentially could be active faults, although no attempt was made to locate all potentially active faults.

Two visits to the region around Koyna Dam and Shivaji Sagar Lake were made on 14 to 16 January 1977, and 22 to 26 October 1978. During the trips, limited ground reconnaissance and a brief aerial survey of the Koyna area were conducted, published and unpublished data were reviewed, and discussions with geologists and seismologists in Bombay, Calcutta, and Poona were arranged. Ground reconnaissance consisted of a general overview of the Koyna Hydroelectric Project and a specific look at the 7-km-long area where ground cracking had been reported to have occurred during the 10 December 1967 earthquake. The aerial reconnaissance consisted of an overview of the stratigraphic and geologic structure of the region during low-sun-angle conditions.

## REGIONAL GEOLOGIC SETTING

Koyna Dam and Shivaji Sagar Lake are located in the northern shield of the Peninsula of India, which is considered to be a seismically stable area. The peninsula is underlain by Precambrian metamorphic and igneous units that have been intensely folded along northwest-southeast axes and subsequently eroded, resulting in an irregular morphologic surface (Berg and others, 1969; Committee of Experts, 1968). The Deccan Trap is comprised of volcanic basalt flows of late

Cretaceous to early Eocene age that unconformably overlie the folded Precambrian units in the west-central section of the peninsula (Figure 4-1).

In the interior of the peninsula, including the Koyna region, the volcanic units are exposed at the surface or are overlain by a 3-m- to 30-m-thick clayey layer of red laterite. The laterite contains bleached zones near the ground surface and in other deeper horizontal zones. These horizontal zones are marked by textural and tonal changes in the laterite and may be useful in detecting tectonic movement that could have occurred during the development of the laterite. The laterite is the youngest unit in the Koyna region, except where overlain by alluvium along river and creek beds.

The Deccan Plateau is an upland area underlain by up to 2135 m of the Deccan basalt flows. The basalt is approximately 915-m-thick at Koyna (Berg and others, 1969), is nearly flat-lying, and generally displays columnar jointing. The plateau is bordered on the west, approximately 9 km west of the reservoir, by a prominent north-south trending escarpment. Along this escarpment, known as the Western Ghats, the plateau drops approximately 700 m westward to a lowland known as the Konkan (Snow, 1973b) (Figure 4-3).

The major structural features identified in the Koyna region include the Tapi-Namada fault zone, an unnamed offshore fault parallel to the west coast of India, the Panvel Flexure, the Cambay Graben, and the Western Ghats (Figure 4-2). These features are discussed in detail below. Seismic activity has been reported to have occurred on all of these features, except for the offshore fault.

The Tapi-Namada fault zone is a northeast-southwest trending structure marked by linear valleys, a graben with a right-lateral strike-slip displacement, and a prominent fold system. The fault zone, which is 500 km north of Koyna, is considered to be active, based on the degree of seismic activity (Guha, personal communication, 1978).

The unnamed offshore fault parallel to the Indian coast has been identified on the basis of geophysical data (Auden, 1975). The type of fault movement has not been conclusively established. Investigators have described it as an east-dipping thrust fault (Guha and others, 1973) and as a normal fault within a graben complex (Auden, 1975). The feature is approximately 140 km west of Koyna and has displayed no significant seismic activity.

The Panvel Flexure, defined as a monoclinal downwarp of the Deccan Trap, occurs north of the town of Panvel and continues southward to within approximately 105 km of the dam (Auden, 1969). Although the downwarp dips 5 degrees to the west, the existence of the feature is debated within the Indian geological community (Gupta, personal communication, 1978). No reported significant seismic activity has been associated with the feature; however, seismic activity along the west coast of India has occurred near the feature (Figures 4-2 and 4-3).

The Cambay Graben is a north-south trending structural basin located approximately 470 km north of Koyna. Faults along the margins of the graben are reported to have Tertiary displacement of the Eocene units (Gambher, 1978). The graben was believed to be truncated at the mouth of the Gulf of Cambay by the Tapi-Namada fault zone; however, recent studies of geophysical data suggest that the graben may continue southward, parallel to the west coast of India and approximately 140 km west of Koyna (Auden, 1975) (Figure 4-2). This postulated southern extension of the graben has been active up to Plio-Pleistocene time (Auden, 1975); however, no significant seismic activity has been reported along the Cambay Graben and the postulated southern extension.

The Western Ghats, as described previously, is a prominent escarpment on the west border of the Deccan Plateau, along the west coast of India (Figure 4-2). The origin of the feature has been a matter of conjecture. It is generally thought to be the result of faulting (up to the east). Although no direct evidence of faulting has been obtained to date (Auden, 1975), Kailasam (1975) postulates a deep seated fault along the northern section of the Ghats (and the Panvel Flexure), based on geophysical data. Seismic activity along the western margin of India has occurred near the escarpment (Figures 4-2 and 4-3) although no causal mechanism has been shown.

## REGIONAL SEISMIC ACTIVITY

The Peninsular Shield of India has generally been considered to be a region of relatively low seismic activity (Figure 4-3). Compilations of data on historic earthquakes by the Committee of Experts (1968) and Gubin (1969) show 50 reported earthquakes (in addition to the two major events at Koyna in September and December 1967) occurring from 1600 to 1968 on the shield (Figure 4-3).

Within a 250-km radius of the Koyna site, 22 earthquakes have been reported (Gubin, 1969). The majority of these earthquakes generally have been of low to moderate intensity; however, seven of the events have had reported or estimated magnitudes greater than 4 (Gubin, 1969). Of the seven events, two have had reported epicenters near Lohagad, approximately 145 km north of Koyna. These two events occurred in 1752 and 1832, and their magnitudes have been estimated at 6.3 and approximately 5, respectively (Gubin, 1969). Another event occurred in 1965 in the Arabian Sea, approximately 80 km southwest of Koyna, and had a magnitude of 5.5. Three of the seven events were along the Western Ghats (Figure 4-3) and occurred in 1967, 1968, and 1969 with reported magnitudes of 4.7, 5.2, and 4.7, respectively. The closest of these events to Koyna, the 1968 event near the town of Pophali and the 1969 Sangemeshar event, occurred within approximately 16 km and 20 km of Koyna, respectively. One of the events occurred on the Deccan Plateau in 1764; its epicenter was approximately 55 km north of Koyna, near Mahabaleshwar.

Although from a review of the historical seismicity, the Koyna region has been generally seismically quiescent, earthquakes of moderate size have occurred. Several of these events that occurred prior to reservoir impoundment were relatively close to the dam and reservoir, the largest of which was near Mahabaleshwar and had a maximum estimated magnitude of 5.5 (Gubin, 1969).

## FAULT INVESTIGATION

Following the 10 December 1967 earthquake, a number of investigators reported observing ground cracks and other geologic phenomena associated with the earthquake (Joshi, 1971; Committee of Experts, 1968). The phenomenon described included ground cracks and fissures, mole tracks, lurching of soft soil blocks, rock falls and slides, water level changes and a few minor cavings. The reported cracks and fissures were features of major interest because they represented possible surface rupture along an existing fault zone during the earthquake, although this hypothesized causal mechanism has not been completely accepted. The purpose of this study, therefore, was to investigate the ground cracking as a causal mechanism of surface rupture along an existing fault and to evaluate whether or not the fault was active prior to the 1967 event, as described by Snow (1973b).

Previous studies of the ground cracks resulting from the 10 December 1967 earthquake produced the following data and information:

1) Ground cracks were observed for a distance from 2.7 km (Committee of Experts, 1968) to 45 km (Snow, 1973b) along a linear trend.

2) The linear trend of ground cracks had a regional orientation of N23°E (Snow, 1973b) and an en echelon pattern (Committee of Experts, 1968).

3) The linear trend of ground cracks formed a zone approximately 200 m wide (Committee of Experts, 1968).

4) Individual ground cracks had generally north-south orientations of N10°E to N25°E (Committee of Experts, 1968).

5) Individual ground cracks were 10 m to 60 m long and varied in width from 2.5 cm to 40 cm.

6) Horizontal displacement along the zone of ground cracks was 5 cm to 10 cm (Committee of Experts, 1968). The sense of displacement is not described but can be inferred to be left-lateral, based on the en echelon pattern described by the Committee.

7) Locally vertical displacement of 10 to 25 cm up to the east was observed (Committee of Experts, 1968).

8) "A fine hair crack" was observed in a basalt outcrop near Kadoli (Committee of Experts, 1968).

9) Small ground cracks trending N20°E to N20°W were observed near Rundhiv. These cracks occurred over an approximately 50-m distance and had depths of less than 1.8 m (Committee of Experts, 1969).

10) Curved ground cracks, possibly related to slope failures, were observed near the villages of Humbarne, Panumbre, Nayari, Runhiv, and Nivle. These cracks had a general east-west trend and were 2 cm to 8 cm wide and 1 m to 1.5 m deep.

11) The zone of ground cracks (except for the curved cracks) was located within the meizoseismal zone (Committee of Experts, 1968).

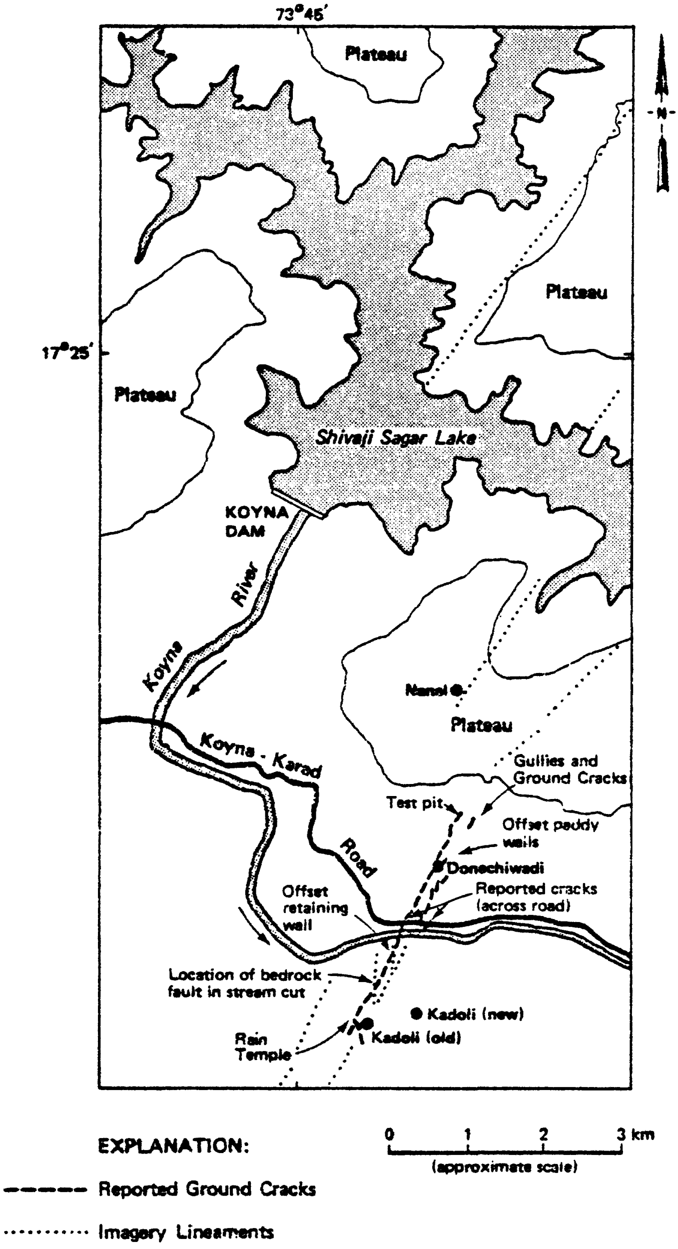
12) Most of the ground cracks were in the surficial lateritic soils (Snow, 1973b).

13) A man-made stone retaining wall was observed to have 30 cm of sinistral displacement within the zone of ground cracks (Snow, 1973b).

From the two visits to the Koyna region for the present study, the following observations were made on the ground cracking resulting from the 10 December 1967 earthquake.

January 1977 Study

During the January 1977 visit, evidence for ground cracking was investigated north of the Koyna River at a reported location approximately 8 km (by road) southeast of the Koyna Dam (Figure 4-4). Actual straight line distance between the reported line of cracks and the Koyna Dam is approximately 3.5 km to 4 km. At this location, cracks were reported to have crossed the road ("48 km to Karad" marker at 8 km south



LOCATION MAP OF REPORTED GROUND CRACKS AND OTHER FEATURES VICINITY OF KOYNA DAM
India

Project No. 14087A

**Woodward-Clyde Consultants**

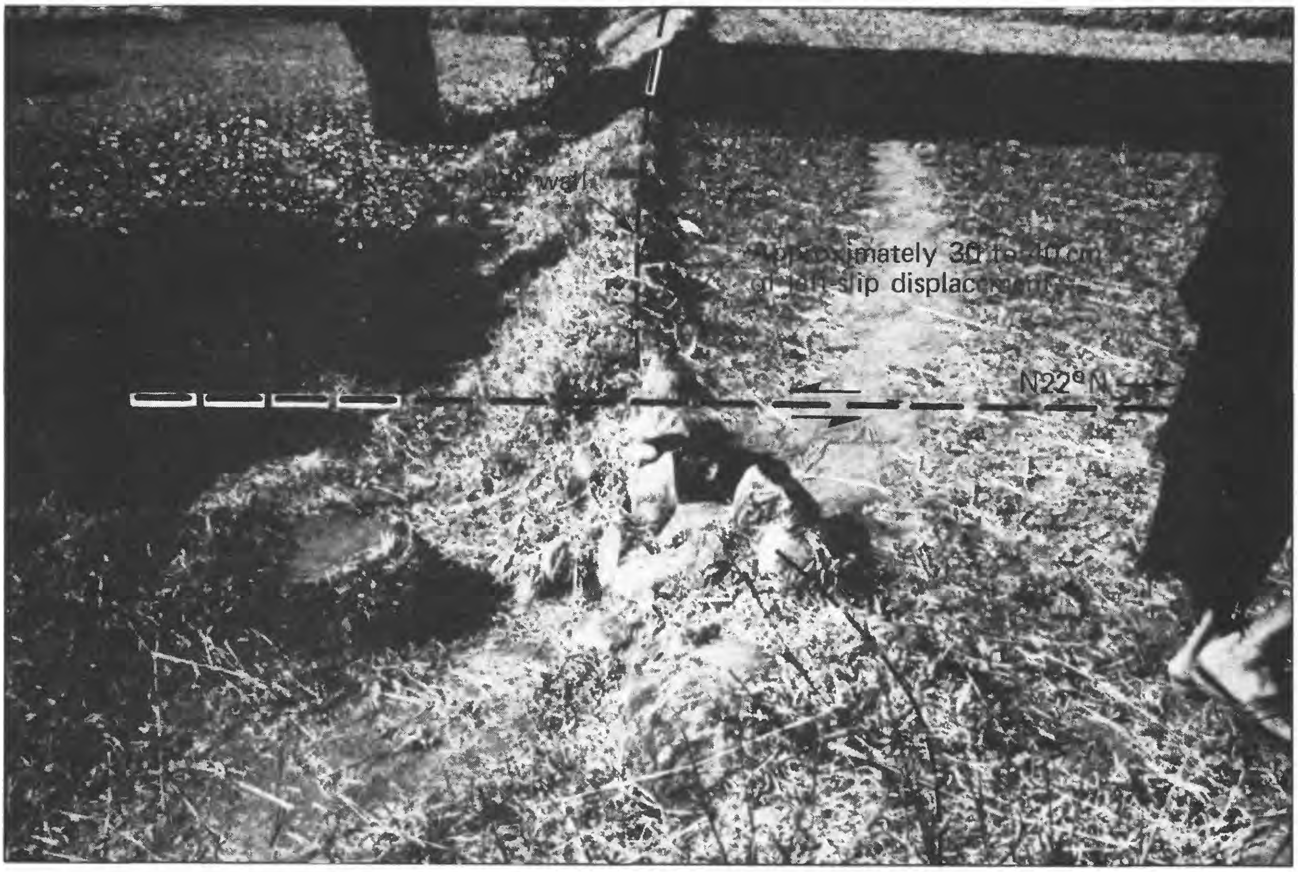
Figure 4-4

of the village of Donechiwadi), which is cut into basalt rock on the north side and built on fill on the south side. The location of the cracks were reported by the local inhabitants to extend northeast of the road through the village of Donechiwadi (Figure 4-4).

Geologic reconnaissance in the Donechiwadi area included a climb to the top of the hill north of the village where a pit had been excavated by the Geological Society of India (Figure 4-4). The pit was still open, but the walls had been affected by sloughing and erosion, thus making it difficult to observe any geologic features. From the area in which the pit was excavated, cracks were reported by the inhabitants of Donechiwadi to have extended to the southwest. A 3-m-deep erosion gully was observed from near the top of the hill to extend down the slope to the break-in-slope at the bottom of the hill (Figure 4-4). The gully may be the feature described by Snow (1973b) as evidence that surface faulting occurred before the 1967 earthquake.

Southwest of the hill are paddy fields that have been leveled and terraced for agricultural purposes. On the south side of each field are stone retaining walls to maintain level ground conditions. From a review of the location and nature of broken and repaired stone walls, in at least one zone, a systematic pattern of breaks had existed in the wall. In response to questions regarding the breaks, the farmers described a zone of cracking 3 m to 5 m wide; the pattern that they drew on the ground to represent the orientation of the cracks was right-stepping en echelon. At the location where the cracks intersected the stone retaining wall, the wall is displaced left-laterally, approximately 30 cm (Figure 4-5).

The farmers explained that, prior to their repairs, the break (offset) in the wall extended over a zone of approximately



OFFSET PADDY WALLS ALONG
ALIGNMENT OF GROUND CRACKING

India

| | |
|---|---|
| Project 14087A | Figure 4-5 |
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3 m. Because of their repairs, the offset now appeared to be localized. The farmers were asked to show exactly where the ground cracks extended across the fields and if there were other similarly damaged retaining walls. In walking through the fields and tracing where the zone of ground cracks occurred, the zone was observed to intersect one rock retaining wall after another along a linear trend. The farmers' description of the crack pattern was consistently right-stepping en echelon. At almost every broken retaining wall the repaired walls showed 30 to 45 cm of left-slip displacement. Some variation in the amount of left-lateral offset appeared from wall to wall; however, such variation may have been more the result of the repairs rather than how much the wall had been displaced.

All of the retaining wall breaks along a linear trend also followed a general, yet somewhat subtle, topographic trend. This clearly suggests geomorphic evidence of a fault. At one locality, a small fracture branched from the main ground crack zone and had about 7 cm of vertical separation of the ground surface. That this crack would still be preserved after nine years was of interest; however, its existence could not be related to any other cause than the ground cracking.

Near the base of the steep hill north of Donechiwadi is a shallow gully following the general trend of the reported ground cracks. The local farmers were asked if this feature was the result of erosion along the zone of cracks resulting from the 10 December 1967 earthquake or whether it existed before the earthquake. The farmers answered that the erosion feature was in existence prior to the earthquake. The reported zone of cracks seemed to be parallel to and to follow the general trend of the topographic feature for some distance. Some erosion along the new zone of cracks had occurred since 1967 and, from a distance, at least three and possibly four somewhat parallel shallow zones of erosion could be observed.

The farmers described three or four zones of cracks that extended almost vertically up the side of the hill north of Donechiwadi. They said that the side of the hill had been extensively shattered along these zones. All the zones are slightly west of the 3-m-deep erosion gully that was previously noted by the field party.

A distinct topographic feature, approximately 2 m high and down on the east, trends diagonally up the hill east of and near the erosion gully (Figure 4-4). The change in elevation occurs across a scarp approximately 6 m wide. The topographic feature could be explained by differential erosion along a contact of left-slip along a fault. There is also a distinct vegetational change across this feature. At the base of the hill and in direct alignment with the apparent scarp is another retaining wall that shows evidence of approximately 1 m of left-slip. The farmers were asked how old the rock walls were, and they answered, "The walls have always been here." (This particular wall had been there for at least five generations.)

In projecting the strike of an assumed fault across the fields at this location, several old walls were in a poor state of repair and seemed to terminate in line with the assumed fault. All of these apparently terminated walls are consistent with the concept of left-lateral slip along the assumed fault.

The reported zone of ground cracks examined across the fields was about 2 km long. All broken walls consistently showed evidence of left-slip where the walls had been broken and were displaced. The amount of left-slip displacement varied from a few centimeters to as much as 1 m, although it was difficult to determine how much of the actual offset was due to repair of the wall. The trend of the reported ground cracks across the broken walls was N22°E.

The local farmers had indicated that the zone of ground cracks had crossed the highway pavement at the main road and near the Koyna River. Except for pavement repair over a distance of about 6 m, no other clear evidence for cracking appears at this location. This location is at a road marker indicating 48 km to Karad, Highway #47. The farmers from Donechiwadi said the villagers across the Koyna River to the south also reported a similar zone of ground cracks, although the farmers had not personally seen the cracks.

### October 1978 Study

The field study in October 1978 involved four days in the region around Shivaji Sagar Lake and Koyna Dam, one day of aerial reconnaissance, and four days of conferring with geologists and seismologists.

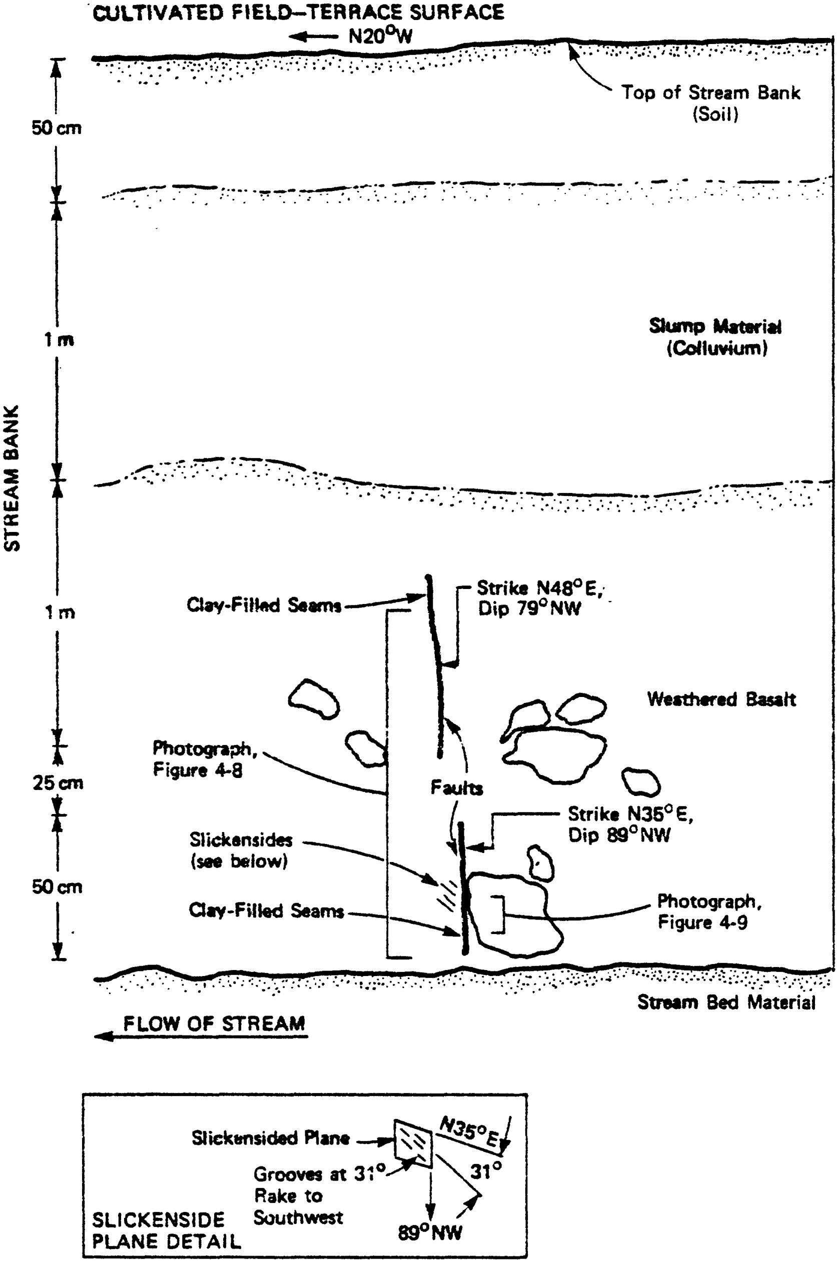
Donechiwadi - The zone of ground cracking was located in the village of Donechiwadi, approximately 3.5 to 4 km southeast of Koyna Dam (Figure 4-4). The ground cracks in Donechiwadi have been described previously by Sinha and Menon (1971), Snow (1973b) and Cluff (1977), among others. Discussions with village leaders permitted relatively accurate location of the zone of ground cracks within the village of Donechiwadi and northward toward the low hill (Figure 4-4). The Indian Geological Survey (GSI) had excavated a test pit on the west side of the low hill; no excavations were made on the east side of the same hill. This test pit was briefly examined. As described in the January 1977 study (Cluff, 1977), this pit is overgrown and partially filled with collapsed material. No ground cracks or remnants were observed on this side of the hill.

Two dominant trends of fracture zones were observed in the Donechiwadi area. Based on information from the local inhabitants and from studies of locations of offset retaining walls and photographs (taken by Gupta and Rastogi, 1976) of cracks crossing the roads, the trends are N10°E for the western zone and N35°E for the eastern zone. Other less evident or shorter crack and fissure zones may have existed: some reports state that ground cracks were observed throughout the hills near Donechiwadi (Phadke, 1968).

The eastern (N35°E) trend of ground cracks (on the east side of the hill north of Donechiwadi) was examined in detail, and individual ground cracks can still be observed within the zone (Figure 4-4). The most prominent of these is now a saddle-like depression trending N35°E on the east hillside. The crack is now 1.3 m wide and 0.5 m deep. (The local farmers report that the feature originally was at least 15 m deep and since has been filled.) Weathered basalt and soil (clay) filling are present on either side of the crack that has clay filling, as shown in Figure 4-6. The length of the crack now is observed to be 2 m.

Several additional ground cracks were observed approximately south-southeast of the prominent zone of ground cracks described above. These additional cracks are observed to trend oblique to the slope of the hillside. They are approximately 1 to 2 m long and approximately 15 to 30 cm deep. Gullying has occurred, but the orientation oblique to the slope (in addition to the villagers' identification of the location of the zone of ground cracking) gives a high degree of confidence to the identification of ground cracks.

The total length of the ground cracks observed is approximately 30 m, and their width is approximately 0.5 m along an approximate N35°E trend. In response to questioning,



LOG OF BEDROCK FAULT EXPOSED
IN NALA (STREAM) BANK
VICINITY OF KOYNA DAM
India

Project No. 14087A
**Woodward-Clyde Consultants**

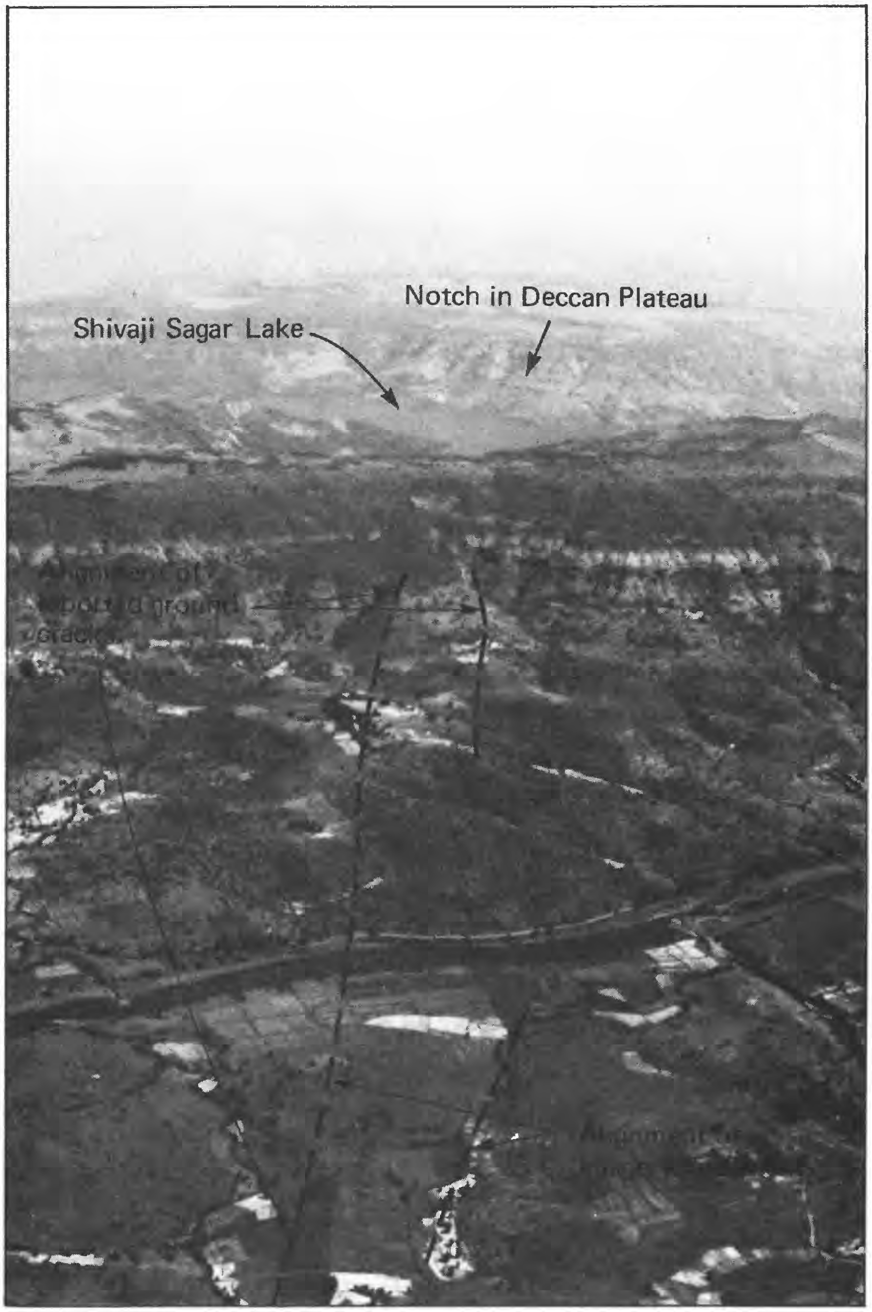
Figure 4-6

the villagers replied that they found no additional ground cracks in the fields below this side of the hill, adjacent to and east of Donechiwadi.

North of the village of Donechiwadi and the low hill is a prominent bluff of the Deccan basalt that rises 100 to 200 m above the plain on which Donechiwadi is located (Figure 4-4). Based on observations of topographic and stratigraphic relationships in this bluff, a notch, whose east side is topographically higher than its west side, may be in the area where the zone of ground cracks is projected to cross the scarp (Figure 4-7). In addition, the stratigraphy on either side of the projected zone of ground cracks could not be correlated across the zone. These data strongly suggest that the zone of ground cracks occurs along an existing fault.

Within the village of Donechiwadi, the natives described a zone of ground cracks approximately 10 to 15 m wide along the west side of the village proper. The main well was reported to have ceased flowing after the earthquake of 1967; water depth at the time of the earthquake was at approximately 70 m in the well. A subsequent boring adjacent to the old well did not encounter water. Because of farming, the ground cracks have long since been cultivated out of existence. However, in the southwest part of the village, the ground cracks, as reported by the natives, passed between a large tree and the corner of a house, thus allowing relatively accurate location of the zone of ground cracking.

Projecting the trend of ground cracks toward the southwest and the Koyna River, the retaining walls, constructed to terrace the land sloping down toward the Koyna River, were examined closely for evidence of displacement, and the villagers were questioned regarding the repairing of the walls. No distinct offsets of the walls were noted along this trend of the ground



TOPOGRAPHIC NOTCH IN DECCAN PLATEAU
ALONG ALIGNMENT OF GROUND CRACKS
VICINITY OF KOYNA DAM
India

| | |
|---|---|
| Project No. 14087A | Figure 4-7 |
| **Woodward-Clyde Consultants** | Page 129 |

cracks at the location indicated by the natives. Analysis of data showed the natives had pointed out a trend of ground cracking to the west of the zone noted in 1977. The two zones of cracking observed high on the hillside north of Donechiwadi correspond to the two separate trends of ground cracking pointed out by the natives as passing east of Donechiwadi and passing through Donechiwadi.

Approximately 500 m south of the village of Donechiwadi, the reported remaining surficial expression of a ground crack was exposed. This feature is oriented normal to the slope of the low hill at the site and is 3 to 4 m long, 30 cm wide, and 15 cm deep. The villagers stated that the feature was a ground crack related to the earthquake along which erosion subsequently has occurred. The orientation of the feature relative to the slope direction does not preclude the feature being an erosional gully. Examination of the feature did not resolve the nature of its origin.

Ground cracking along the road between Koyna and Karad, immediately adjacent to the "48 km to Karad" road marker (Figure 4-4), has been reported previously (Committee of Experts, 1968). Approximately 100 m east of the road marker and the zone of ground cracking is an outcrop on the north side of the road [see also Cluff (1977) description of the location]. Stories conflicted regarding the location of the zone of ground cracking relative to this outcrop. Initially the zone was shown to cross the road at the east end of the outcrop. Subsequently, the zone is shown to cross at the west end of the outcrop, on the west facing slope of the outcrop and the adjacent gully. On the basis of this investigation, the second location is judged to be the more accurate because many, if not all, of the villagers present tended to overrule the eastern location, although the eastern location may represent the easternmost zone of the two trends of ground cracking.

The outcrop was examined in detail and consisted of prominently jointed basalt. No evidence of fault displacement was observed. The predominant joint orientation was N15°W to N20°W and had generally a steep northeast dip. Joints were observed to be generally tight and devoid of infilled or secondary material. In addition, no fault gouge, slickensides, or shear zones were observed to be present. The surficial soil units were thin to nonexistent. Erosion appears to be stripping away any soil cover that has developed.

Whether the origin of the western zone of ground cracking in the vicinity of Donechiwadi was from differential settlement, slumping, or fault displacement could not be readily determined from this examination. To assess if the ground cracks were of tectonic origin, a location would have to be selected for examining the zone for evidence of active faulting; finding such a location in a short period of time in the area around Donechiwadi was considered unlikely. Consequently, the zone of ground cracking (reported by the Committee of Experts, 1968) was examined for such evidence on the south side of the Koyna River near the village of Kadoli.

<u>Kadoli</u> - The villagers indicated the location of the zone of ground cracks in the vicinity of Kadoli (Figure 4-4, south of the Koyna River). This location appears to contradict Plate 5-1 in the report of the Committee of Experts (1968), unless the arrow (on the plate) showing the direction to Kadoli is reversed 180 degrees. The villagers were very emphatic in locating the ground cracks at the location shown on Figure 4-4, and the described zone was oriented N30°E. South of the Rain Temple, the ground cracks were observed to have continued for approximately 500 m to the crest of the hills south of the temple. The villagers did not know if the ground cracks continued south of the hill crest because no

villager had gone to the other side of the hill to look for them. The zone was reported to have been 10 m wide and to have consisted of a nearly continuous central crack flanked on either side by one to three additional cracks. When requested to draw what was observed, the villagers drew a configuration with no apparent en echelon stepping of the cracks. The main crack was reported to have been 10 cm wide and 70 to 100 cm deep. The flanking fractures were 2 to 5 cm wide, 70 to 100 cm deep, and 2 to 3 m long.

Between the Rain Temple and the Koyna River, the zone of ground cracks crossed two stream drainages. The southern-most drainage and the Koyna River bank both were examined for evidence of faulting, but none was observed. In the northern drainage, however, a fault was observed within or adjacent to the reported zone of ground cracking (Figure 4-6). The fault was located in the northeast bank of a small stream drainage south of the Koyna River (Figure 4-8). Its orientation was N35°E and nearly vertical. Close inspection of the fault showed two distinct near-vertical shears in weathered basalt. The upper shear has a strike of N48°E and dips 79°NW. The lower shear strikes N35°E and dips 83°N. Both shear zones contain zones of clay up to 8 cm thick. The surface of the margin of the clay zone and other planes within the clay are polished. Slickensides were observed on some planes and on the edge of a small cobble adjacent to and in contact with the clay zone. A polished pebble was found in the clay zone with the long direction of the pebble oriented parallel to the grooves in the slickensided clay planes (Figure 4-9). Well-defined manganese-stained slickensided planes were measured to have a strike of 35°E and a rake of 31°SW. The clay-filled zone was traceable for 1.6 m from the base of the stream bank upward through weathered basalt to near the ground surface where slumped reddish brown soil (pebbly colluvium) obscured the structure, as shown in Figures 4-8 and 4-9.

FAULT PLANE EXPOSED IN
BEDROCK ALONG RIVER BANK
VICINITY OF KOYNA DAM
India

| | |
|---|---|
| Project No. 14087A | Figure 4-8 |
| **Woodward-Clyde Consultants** | Page 133 |

SLICKENSIDES ON FAULT PLANE
VICINITY OF KOYNA DAM
India

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 4-9

Based on observations of this exposure, a bedrock fault is demonstrated to be present at a location adjacent to or within the reported zone of cracking and fissuring that accompanied the December 1967 earthquake. The clay-filled seam has the same strike (N35°E) as the regional trend of the surficial ground crack zone. The low angle (31°SW) measured on the rake of the slickensides is consistent with other reports of strike-slip, left-lateral displacement occurring during the December 1967 earthquake (Committee of Experts, 1968). The rake of the slickensides also is consistent with the reported uplift of the ground by as much as 25 cm (Committee of Experts, 1968). Thus, the left-lateral displacement along a rake of 31°SW would result in the east side of the fault zone being uplifted.

The age of the weathered basalt at this location was not determined during this study. The observed thickness of the basalt was 1.6 m, and it was overlain by sediments that are probably very young (deposited within the last few years) and that were not measureably displaced by the fault. Thus, based on presently available data, displacement along this fault in this segment of the ground crack zone prior to the 1967 event can not be evaluated.

North of the bedrock fault exposed in the drainage near the Koyna River and within the zone of reported ground cracking, a retaining wall was observed to have incurred left-lateral displacement of approximately 45 cm (Figure 4-4). The time of displacement of this wall could not be determined from the local farmers; consequently, whether the observed displacement took place during the 1967 event or whether some of the displacement occurred prior to the 1967 event still is not known.

Aerial Reconnaissance - An aerial reconnaissance was made of the region between Bombay and Koyna. Reduced visibility in Bombay delayed the scheduled early morning (low-sun-angle) overflight; as a result, the reconnaissance was a mid-morning view of the Shivaji Sagar Lake region.

The ground crack zone was observed to continue as a linear feature north of the village of Donechiwadi to the crest of the ridge between Donechiwadi and the eastern arm of the reservoir (north of Koyna Dam) (Figure 4-7). The linear feature was not observed to continue northward into the arm of the reservoir. However, the feature was observed to trend to within approximately 2 km of the reservoir, which is within the hydrologic regime of the reservoir.

South of the village of Kadoli, the linear feature associated with the zone of ground cracking was observed to continue for 2 km south of the village. Therefore, the fault zone associated with the zone of ground cracking is inferred to be 8 km long, based on the ground observations and the aerial reconnaissance.

## CONCLUSIONS

1) Surface faulting occurred during the 10 December 1967 earthquake, the epicenter of which was located within several kilometers of the Koyna Dam. Surface faulting occurred about 3.5 to 4 km southeast of the dam and extended for a length of at least 7 to 8 km from north of Donechiwadi, across the Koyna River, to south of Kadoli.

2) Measurements made at an exposure of weathered bedrock in a stream bank near Kadoli show a northeast-trending fault dipping slightly to the west. Measurements made on the polished slickensided surfaces in the clay gouge within

the fault zone show a rake angle of 31°SW, indicating the occurrence of strike-slip movement (sinistral) with a normal component (west side down).

3) The general projection of the fault exposed in the stream bank was identifiable during aerial reconnaissance as a lineament defined by tonal contrasts and aligned with geomorphic features including stream courses, springs, topographic benches, and an apparent interruption in the bedding of the Deccan Trap.

4) The fault location in the stream bank and the location of geomorphic features characteristic of recent faulting are in alignment with ground cracks and fissures that originated during the 1967 earthquake, as pointed out in the field by several independent groups of local residents from Donechiwadi and Kadoli.

5) The fault location in the stream bank is also coincident with locations of ground cracks and fissures south of the Koyna River, mapped by the Geologic Society of India soon after the occurrence of the 1967 earthquake.

6) The conclusion that surface faulting occurred along a west-dipping, northeast-trending, high-angle fault as a result of the 10 December 1967 earthquake is generally compatible with reported seismic data, such as epicenter locations and fault plane solutions.

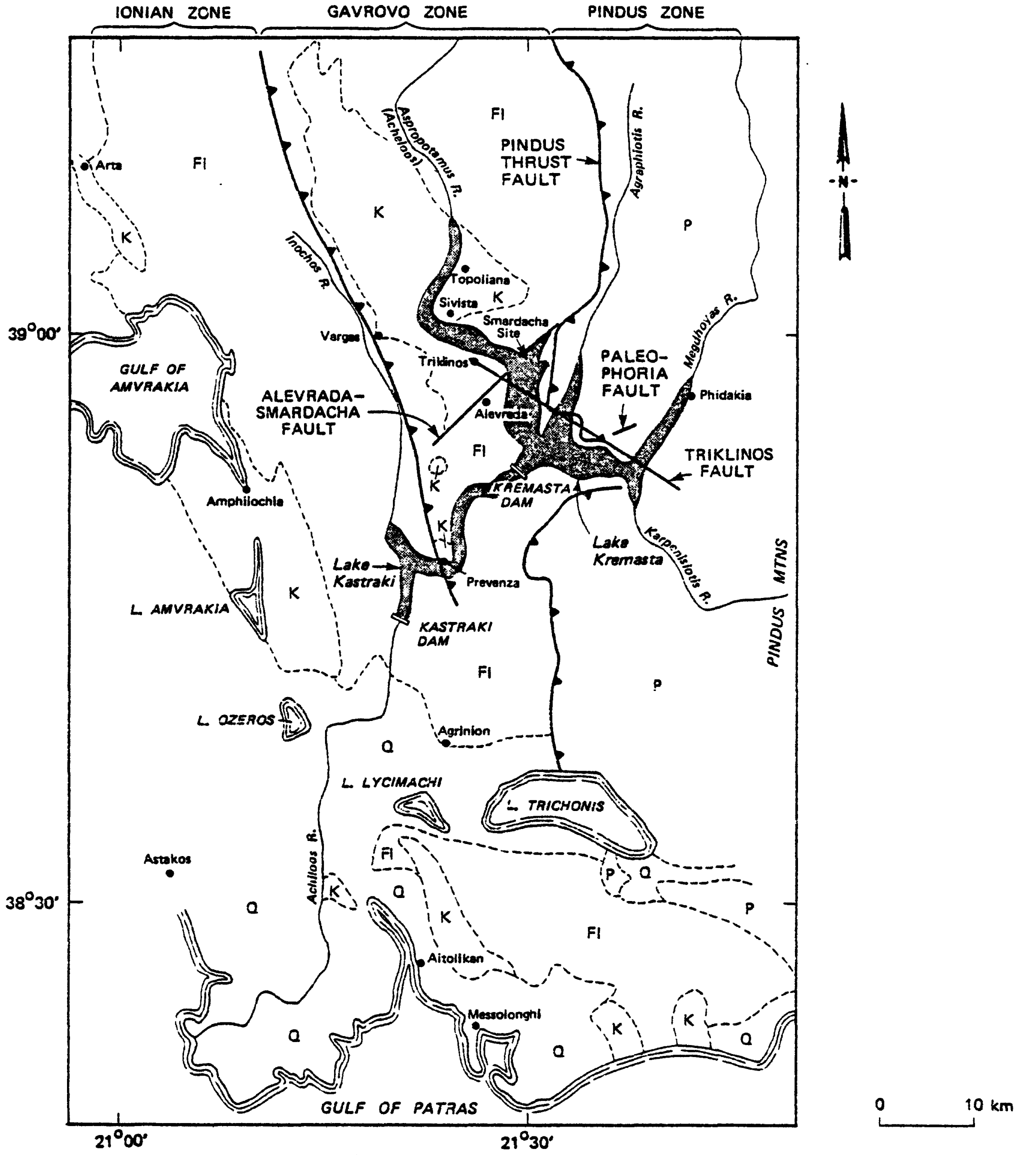
7) Offset retaining walls along the zone of ground cracking and the reported repeated offsets during historical time indicate that the ground cracking occurred along an active fault that has had displacement in historical time.

## 4.3 KREMASTRA/KASTRAKI DAM REGION, GREECE

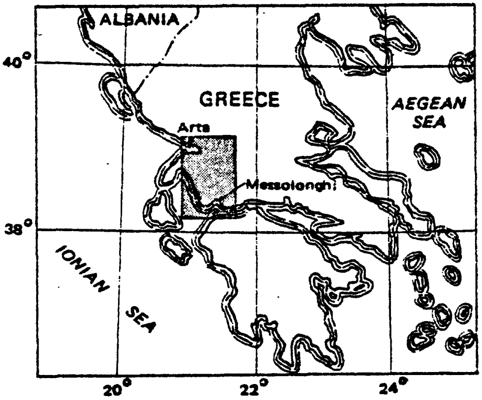
### INTRODUCTION

Kremasta Dam, in southwestern Greece, impounds the Acheloos River, forming Lake Kremasta, which is approximately 120 m deep (Figure 4-10). Approximately 20 km downriver from Kremasta Dam, is Kastraki Dam, which impounds Lake Kastraki. This lake is approximately 86 m deep and is backed up to Kremasta Dam. Because these two lakes essentially form a continuous reservoir from Kastraki Dam to the north end of Lake Kremasta, they are treated as a single hydrologic entity in this study and will be referred to as the Kremasta reservoir.

Prior to reservoir impoundment, the region in which the lake is located experienced historical earthquakes, as shown on Figure 4-11. However, this seismic activity was less than that of other nearby areas in Greece, and none of the historical earthquakes was reported to have occurred in the Kremasta Dam and reservoir area (Galanopoulos, 1967; Gupta and Rastogi, 1976). Subsequent to impoundment of the reservoir on 21 July 1965, seismic activity commenced and was clustered within approximately 25 km of the reservoir. This activity appeared to be occurring along existing fault zones at focal depths ranging from less than 2 to 20 km (Comninakis and others, 1968). The largest of these events (magnitude 6.3) occurred on 5 February 1966, 25 km from the lake, as the lake approached maximum depth for the first time after impoundment (Comninakis and others, 1968) (Figures 4-11 and 4-12).



LOCATION MAP



EXPLANATION

| | |
|---|---|
| Q | Neogene–Holocene Continental Deposits |
| Fl | Flysch, mainly Eocene |
| K | Limestone, mainly Cretaceous |
| P | Cherts, shales, limestones of the Pindus zone |

GENERALIZED GEOLOGIC MAP
AND LOCATION OF
KASTRAKI AND KREMASTA DAMS
Greece

Project No. 14087A
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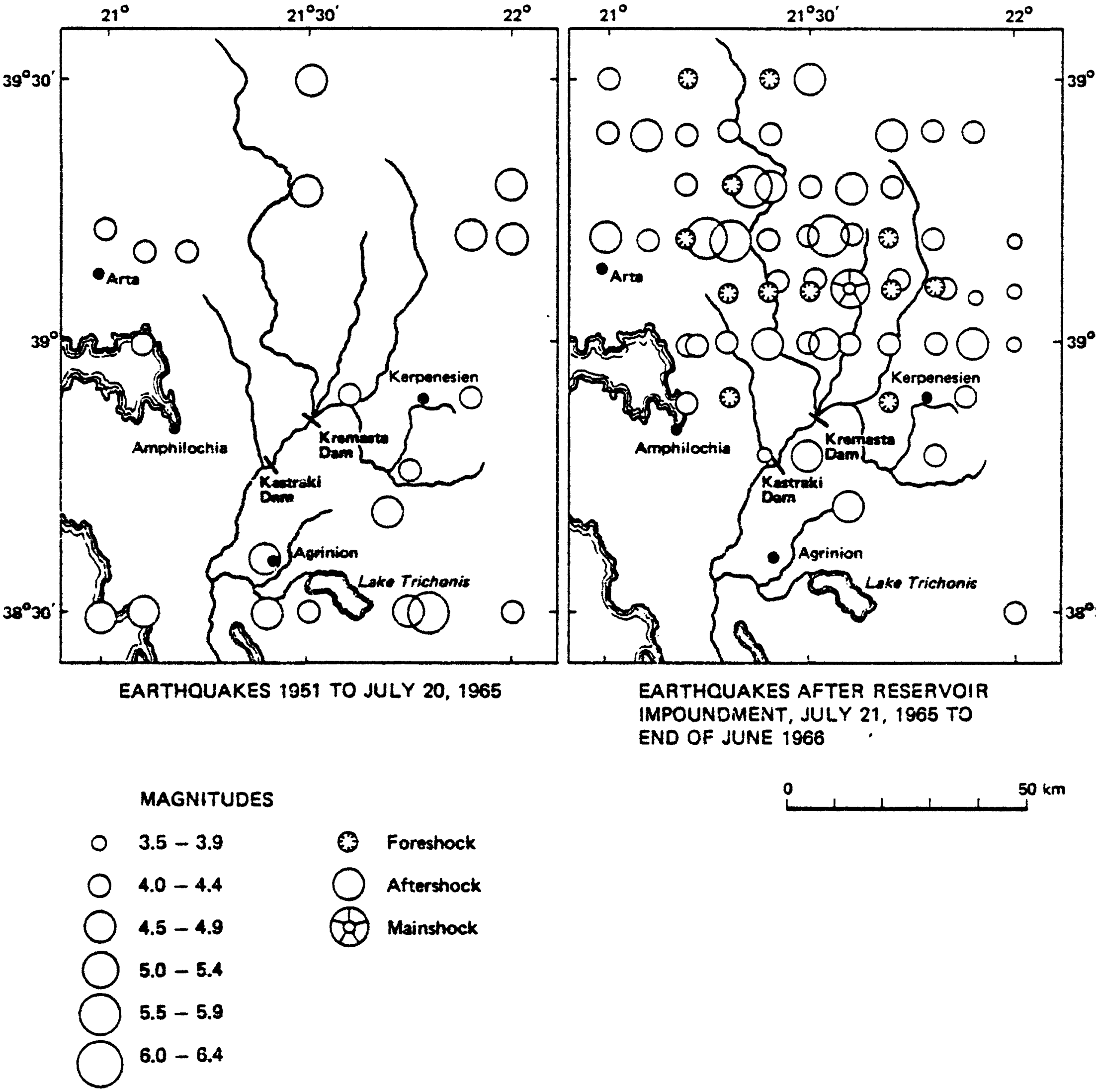
Figure 4-10



EARTHQUAKES 1951 TO JULY 20, 1965

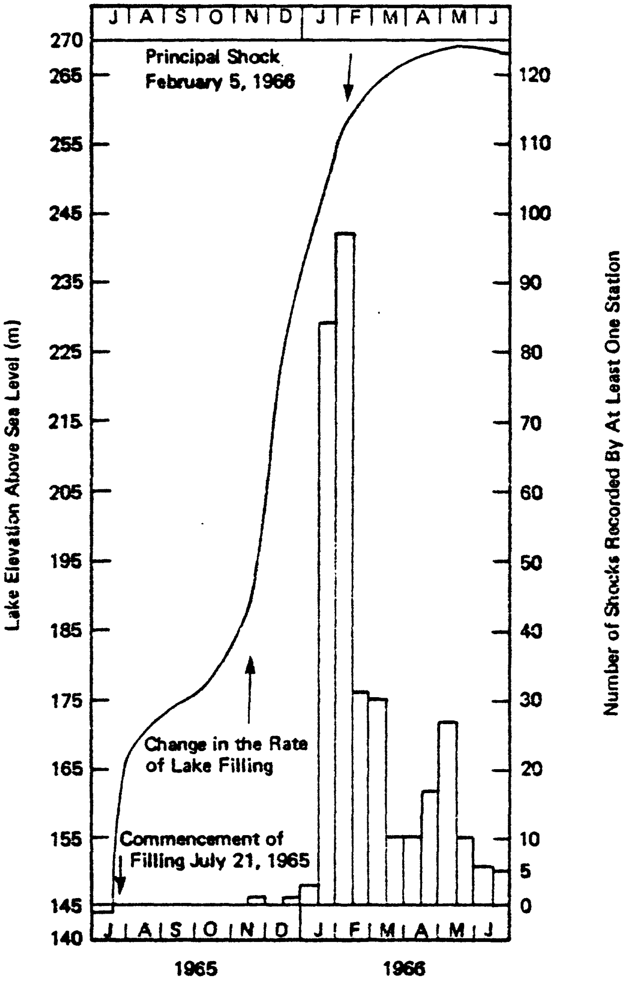
EARTHQUAKES AFTER RESERVOIR IMPOUNDMENT, JULY 21, 1965 TO END OF JUNE 1966

Source: Modified from Galanpoulos (1967b)

HISTORICAL SEISMICITY MAP OF THE KREMASTA-KASTRAKI AREA
Greece

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 4–11



Source: After Galanopoulos (1967b)

WATER ELEVATIONS AND
SEISMIC ACTIVITY
KREMASTA LAKE
Greece

| | |
|---|---|
| Project No. 14087A | Figure 4–12 |
| **Woodward-Clyde Consultants** | Page 141 |

The temporal and spatial relationship between reservoir impoundment and the seismic activity suggests that seismicity was triggered by impoundment of the reservoir. The magnitude 6.3 event is one of the largest events associated with impoundment of a reservoir (Packer and others, 1977; Simpson, 1976; Gupta and Rastogi, 1976). The Kremasta reservoir area was selected for field study because of this close relation of the seismic activity to reservoir impoundment and because of the size of the largest event. The purpose of the study was to evaluate if active faults are present within the influence of the reservoir. The scope of these studies was limited and did not attempt to locate all possible active faults. For the purpose of this study, an active fault is a fault that has had displacement in the present tectonic stress regime.

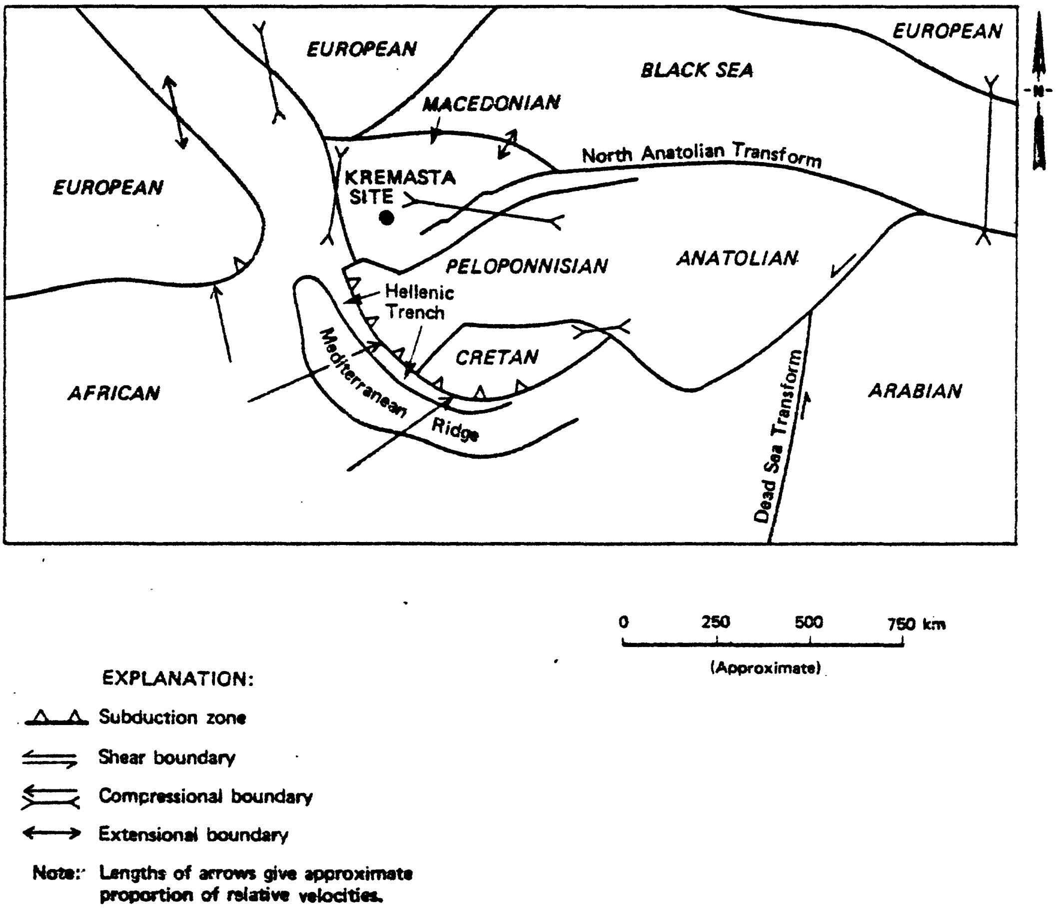
Geologic reconnaissance of the Kremasta reservoir area was made from 1 to 9 November 1978, aerial reconnaissance of the region was conducted on 8 November 1978. Discussions with geologists and seismologists familiar with the Kremasta reservoir area were held in Greece and Europe.

## REGIONAL GEOLOGIC SETTING

The plate tectonics setting in which the Kremasta reservoir area is located is one of the most complicated plate tectonic environments known to exist. According to prevailing plate tectonics theory, the African Plate is moving northward relative to the European Plate, generally resulting in horizontal compression in a north-south direction within the Mediterranean Sea and the Alpine area (McKenzie, 1972). To explain the complex tectonic relationships within the Mediterranean region, several authors have proposed the existence and influence of a series of small plates, subplates and scholles (McKenzie, 1972; Dewey and Sengor, 1979). The Kremasta reservoir area is located near the southern margin of a small plate identified by Dewey and Sengor (1979) as the Macedonian Plate (Figure 4-13). The boundaries of the plate are somewhat obscure in the Kremasta reservoir area, but the general plate movement is believed to be toward the southwest and results in right-lateral shearing occurring off the west coast of Greece (Drakopoulos, personal communication, 1979). In addition, the east-west to northeast-southwest (right-lateral) trend may extend into the Kremasta reservoir area in the Gulf of Korinthiakos.

Within this plate tectonic framework, the Kremasta reservoir is located in the Gavrovo Zone, a north-trending thrust zone that is bordered on the west by the Ionian Zone and on the east by the Pindus Zone (Figure 4-10) (Aubouin, 1959). The Gavrovo, Ionian, and Pindus zones are characterized by westward thrusting and folding upon which are superimposed generally north-trending thrust faults and east-northeast trending wrench faults (Gupta and Rastogi, 1976; Snow, 1971; British Petroleum Company, Ltd., 1971). The three zones are separated by generally north-trending, east-dipping thrust fault zones. The thrust fault zones developed during the Pindic orogeny in Miocene time as did the folding (Snow, 1971). The wrench fault zones, including the Alevrada-Smardacha fault, cut across and post-date the Miocene age structural features. The age of these fault zones has not been determined, although the results of this study suggest that they may have experienced very recent displacement, as discussed below.

Kremasta Lake is crossed by numerous faults. The major faults that have been previously mapped in the dam and reservoir area include the north-trending, east-dipping Pindus thrust fault and the northeast-trending, right lateral Alevrada-Smardacha fault (Figures 4-10 and 4-14).



Source: After Dewey and Sengor (1979)

SCHEMATIC DIAGRAM OF
PLATE TECTONIC SETTING
OF WESTERN GREECE

Project No. 14087A

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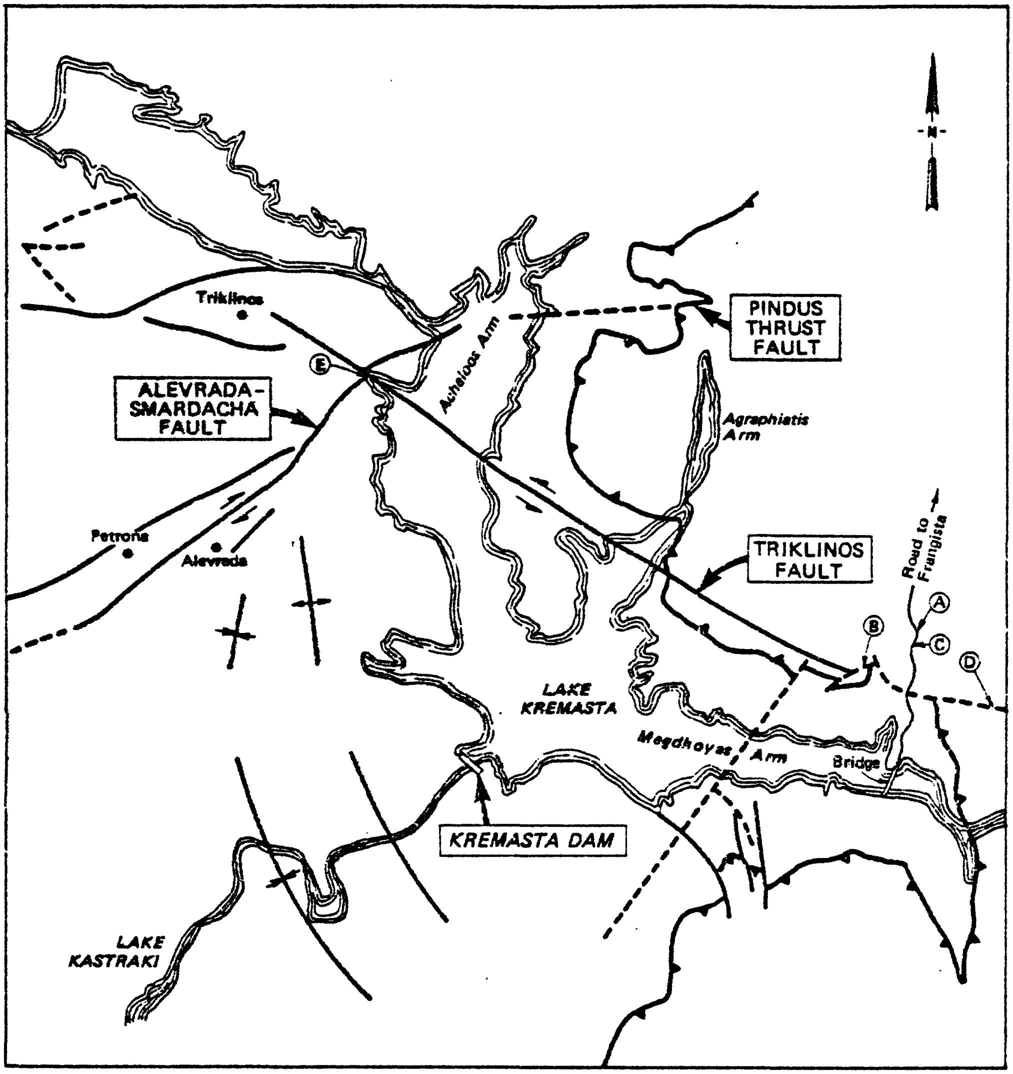
Figure 4-13



**EXPLANATION:**

**Locations (approximate) referred to in report:**

Ⓐ Pindus Thrust Fault
Ⓑ Village of Paleophoria
Ⓒ Paleophoria Fault
Ⓓ Triklinos Fault
Ⓔ Displacement by Triklinos fault
– – – – Inferred fault
——— Fault trace, relative movement indicated

0 2 4 6 km

Source: Modified from British Petroleum Co., Ltd. (1971)

FAULTS IN LAKE KREMASTA AREA

Greece

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 4-14

The Kremasta region is underlain by eastward-dipping sedimentary strata. At depth are Cretaceous limestone units which have extensive karstification and are overlain by Eocene limestone. Uplift during early Miocene time resulted in extensive flysch deposits of mudstone and siltstone, sandstone and local conglomerate. The Ionian, Gavrovo, and Pindus zones have north to north-northwest trending belts of strata (Aubouin, 1959) that exhibit similar facies along their length but differ from the facies in adjacent zones (Aubouin, 1957; British Petroleum Company, Ltd., 1971). The boundaries between these zones are fault zones, as described previously; however, the faults are believed to be superimposed on sedimentological breaks or boundaries (British Petroleum Company, Ltd., 1971) (Figure 4-10).

Within the Ionian zone, rock units include Triassic evaporites, Jurassic limestone, chert, some shale, and upper Eocene limestone. Unconformably overlying these units are the Miocene flysch deposits, which are relatively thick in the east and become thinner and more calcareous in the west. Locally, marl and conglomerate are present in the western part of the zone. Overlying the Miocene deposits are Pliocene alluvial and lacustrine deposits and Pleistocene alluvial and beach deposits of silt, sand, and gravel (British Petroleum Company, Ltd., 1971).

The Gavrovo zone contains Upper Cretaceous limestone unconformably overlain by Eocene limestone and Miocene flysch. The lowermost units, generally limited to the eastern section of the zone, are in the form of inliers in the flysch deposits. Most of the Gavrovo zone is composed of thick Miocene deposits of arenaceous flysch. Overlying the Miocene units are Pliocene and Pleistocene alluvial and lacustrine deposits (British Petroleum Company, Ltd., 1971).

The Pindus zone is composed of Jurassic and Cretaceous siliceous limestone, shale, and radiolarite. Unconformably overlying these units are Upper Cretaceous and post-Mesozoic flysch deposits (Snow, 1971). Ophiolites, shale, and radiolarian chert were observed during this study to occur locally in the zone.

## SEISMOLOGIC SETTING

Prior to reservoir impoundment, the Kremasta region had experienced historical earthquakes. However, the activity was less than that of other nearby areas in Greece, and none of the historical earthquakes were reported to have occurred in the dam and reservoir area (Galanopoulos, 1967; Gupta and Rastogi, 1976; Comninakis and others, 1968) (Figure 4-11). Data presented by Galanopoulos (1967) indicate seismic activity in the Lake Trichonis area and northwest and northeast of the reservoir area. Moreover, an event of magnitude less than 4.4 was recorded in the vicinity of the Kremasta area prior to impoundment. According to Snow (1971), Galanopoulos reported only two earthquakes in the Acheloos River area for the 265-year period prior to reservoir impoundment. Gupta and others (1972a) report no seismic activity within 40 km of the dam prior to impoundment of the reservoir.

Impoundment of Kremasta Lake began on 21 July 1965. Shocks were felt in the vicinity of the lake in August 1965 and became swarms of earthquakes in December 1965 and January 1966 (Figures 4-11 and 4-12). From 1 January 1966 to 4 Feburary 1966, 81 earthquakes occurred within approximately 96 km of the reservoir (Snow, 1971).

From 15 January to 20 January, 1966, 6 to 8 earthquakes were recorded each 24 hours, and engineers working at Kremasta Dam reported feeling sudden shocks. Engineer Stathmu reported the following events (Galanopoulos, 1967a):

| | | |
|---|---|---|
| 16 January 1966 | 4:15 am | Strong vibrations (estimated M = 4 or 5) |
| | 10:04 pm | Strong vibration |
| 18 January 1966 | 5:39 am | Strong vibration |
| 19 January 1966 | 4:50 am | Strong vibration |
| | 9:15 am | Weaker vibration |
| | 4:35 pm | Weaker vibration |

Five of these events were recorded at the seismograph station on Kephallenia Island, 115 km west of Kremasta. Two of the events were recorded at the cental seismograph stations in Athens, 220 km to the southeast.

On 5 February 1966, a magnitude 6.3 earthquake occurred near the north shore of Lake Kremasta, 25 km north of Kremasta Dam, epicenter coordinates at 39°N, 21.6°E (Simpson, 1976; Comninakis and others, 1968). Aftershocks were recorded through the remainder of 1966. Comninakis and others (1968) reported that 740 foreshocks and 2589 aftershocks, between magnitudes 2.0 and 5.6, were recorded by the Seismological Institute of the National Observatory of Athens Network. Calculated focal depths are 24 km, 23 km, and as shallow as 20 km (Comninakis and others, 1968).

Two fault plane solutions for the main event are reported in the literature. In the Bulletin of the International Seismological Center, the calculation of first-motion data indicates that plane a is oriented N72°E, 62°NW and has a slip angle of 60 degrees. Plane b is oriented N58°W, 40°SW and has a slip angle of 48 degrees. The plane b direction is oriented parallel to the trend of one of two faults traced by Galanopoulos (1967b) and is accepted by Gupta and others (1972b) as the fault plane. Movement on the plane is accepted to be normal sinistral, and the dip component of motion is at a 48-degree angle.

The second solution for the main event is based on P wave data recordings from 80 stations (Comninakis and others, 1968). By combining the solution with the distribution of foreshocks and aftershocks, Comninakis and others (1968) have identified a fault plane with an orientation of N66°W and a dip of 76 degrees. Displacement is explained as reverse (a vertical thrust fault) with a sinistral component.

## FAULT INVESTIGATION

Three major structural features in the Kremasta area were identified during the ground and aerial reconnaissance for this study. They are the Pindus thrust fault, the Alevrada-Smardacha fault, and an unnamed northwest-trending, high-angle fault (referred to here as the Triklinos fault) not previously reported in the literature (Figures 4-10 and 4-14). All three faults are of regional nature and pass through Lake Kremasta. They are all marked by prominent linear topographic features. Although many other bedrock faults were observed in the area around the reservoir, these three faults were the most prominent and were in the proximity of the epicenter of the 5 February 1966 earthquake. In addition, a northeast-trending, high-angle fault with circumstantial evidence of recent displacement near the lake (referred to here as the Paleophoria fault) was studied in some detail because of its prominence, possible recent displacement, and proximity to the reservoir (Figure 4-10). The results of the observations made along these faults during this study are presented below.

### Pindus Thrust Fault

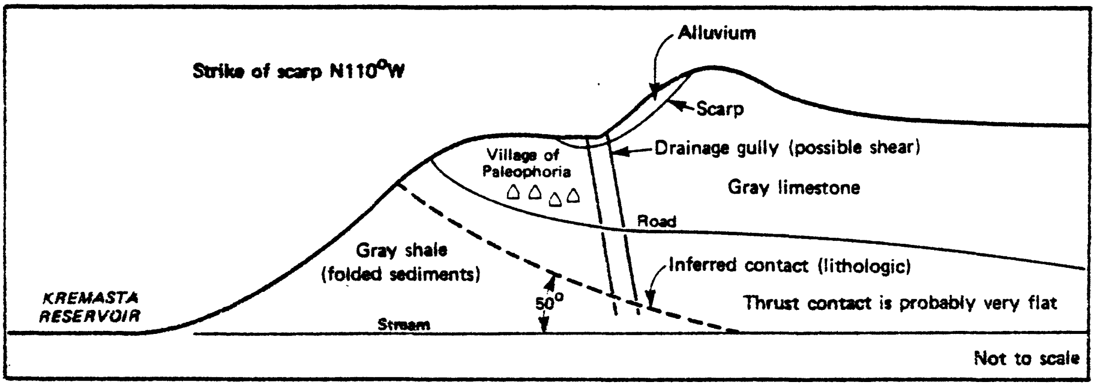
The Pindus thrust fault is a Miocene age fault along which Triassic, Jurassic, and Cretaceous age chert and limestone units were thrust to the west, overriding Miocene age flysch deposits. The fault is located in the eastern section of the Lake Kremasta area and crosses the Megdhoyas and Agraphiatis arms of the lake (Figure 4-14). The fault generally was inaccessible during this reconnaissance study except at the location where it crosses the road to the village of Frangista (Location A, Figure 4-14). In this region, however, the Pindus thrust is cut off on the east side of the road to Frangista by high angle faults and was observed only on the west side of the road near a small village called Paleophoria (Location B, Figure 4-14).

Based on observations during ground and aerial reconnaissance, the leading edge of the thrust sheet appears to correspond to a prominent topographic scarp where light gray limestone of the Pindus zone lies above the dark gray siltstone flysch deposits of the Gavrovo zone (Figure 4-15). This contact, although visible from a distance, generally was inaccessible during the reconnaissance study. From short traverses on foot along ravines eroded into the scarp, the scarp was observed to be covered with landslide debris and large blocks of limestone. Springs are also present along the base of the scarp. From this review of a short segment of the Pindus thrust fault zone, no evidence of recent displacement was observed.

### Paleophoria Fault

High-angle faulting was observed on the east side of the road to Frangista, approximately 4 km north of the bridge crossing the Megdhoyas arm of the reservoir (Location C, Figure 4-14). The fault can be observed in a vertical exposure of approximately 500 to 700 m in the hillside above the stream draining from

WEST VIEW



PINDUS THRUST FAULT NEAR
PALEOPHORIA
Greece

Project No. 14087A
**Woodward-Clyde Consultants**

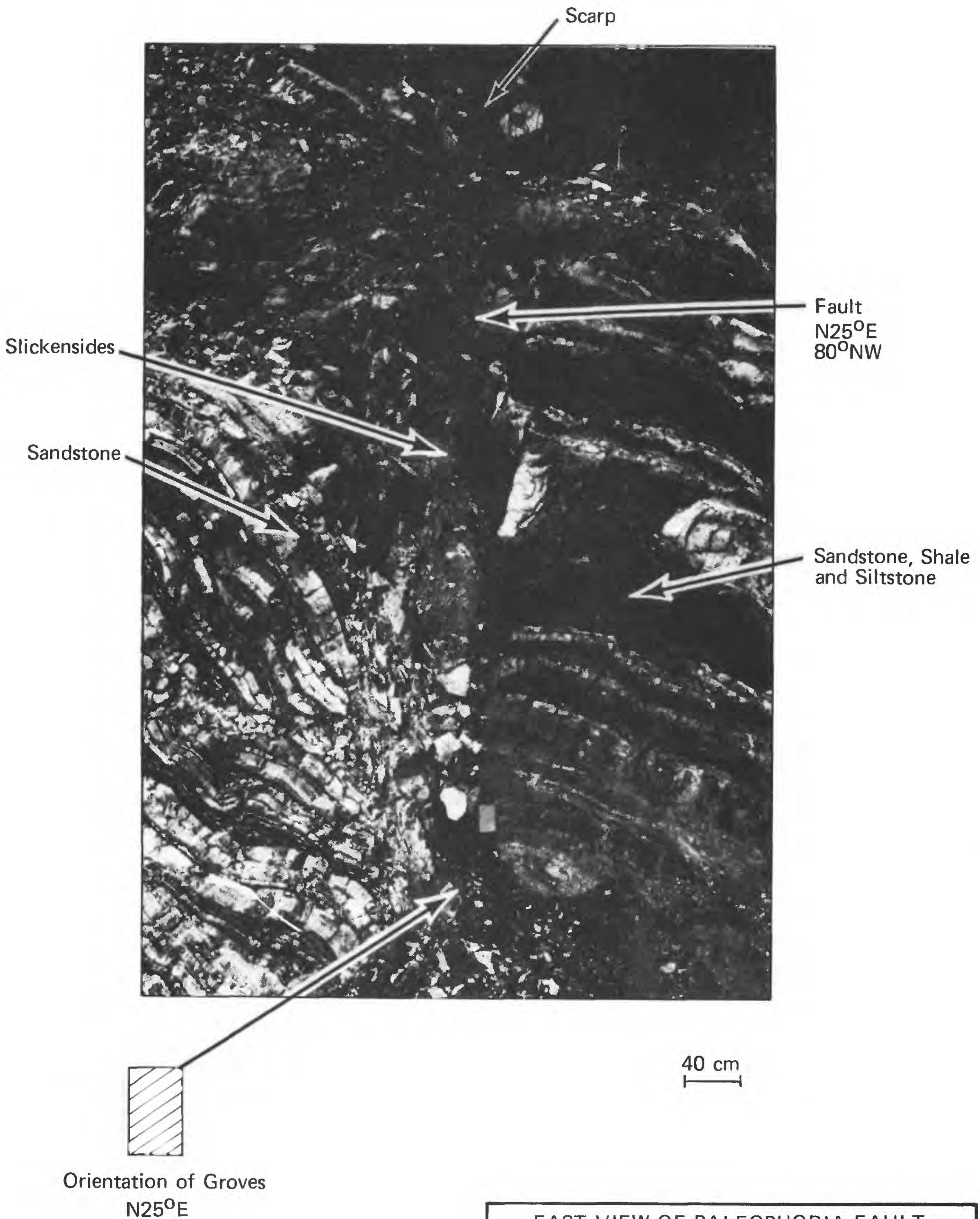
Figure 4-15

Frangista to the lake (Figure 4-16). The amount of displacement could not be determined but appears to be large (at least 10 to 90 m). The fault is oriented N25°E, 80°NW to approximately 60°SE, its southeast side downthrown relative to its northwest side (Figure 4-16).

The fault is within the flysch deposits and separates reddish-brown siltstone on the southeast wall from grayish-white sandstone on the northwest wall. This gouge zone is 40 to 50 cm wide and contains slickensides which dip 25 degrees to the southwest. Because of the down-dragged bedding and the orientation of the slickensides, the fault may be normal, its lateral displacement resulting from a more recent reverse. The soil horizons above the fault zone generally were inaccessible; however, a topographic scarp (up on the northwest side) was observed above the fault zone. The orientation of the slickensides within the upper section of the fault zone suggests that a reverse, dextral displacement has occurred, post-dating the period of normal faulting. The orientation of the fault (cross-cutting Miocene regional trends) suggests that the original normal faulting occurred in post-middle Miocene time. Thus, although no direct evidence for recent displacement was observed; circumstantial evidence suggests that relatively recent displacement may have occurred.

### Alevrada-Smardacha Fault

The northeast-trending Alevrada-Smardacha fault zone has been mapped along a distance of 28 km (British Petroleum Company, 1971) and is several hundred meters wide. The fault is shown to offset dextrally north- to northwest-trending, broadly folded structures in the lower Miocene flysch deposits in the Gavrovo zone. The Alevrada-Smardacha fault is easily identified near the village of Alevrada by a high linear cliff of white to gray massive Cretaceous and Eocene limestone on the northwest side of



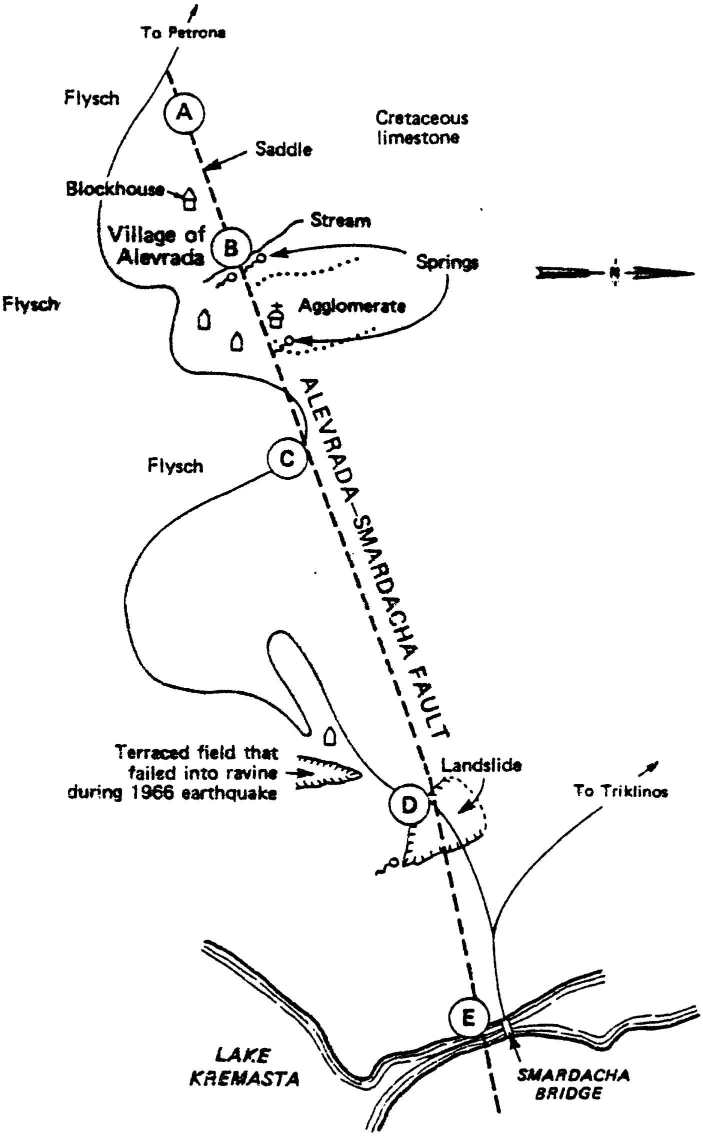
EAST VIEW OF PALEOPHORIA FAULT
NEAR MEGDHOYAS BRIDGE
VICINITY OF KREMASTA-KASTRAKI
Greece

| | |
|---|---|
| Project No. 14087A | Figure 4-16 |
| **Woodward-Clyde Consultants** | Page 153 |

the fault zone. On the southeast side of the fault zone are lower Miocene flysch deposits, which, in places, are cut through by the fault. From the air, the fault is identified by a series of parallel linear elements. At some locations, the fault is at the contact of the flysch with limestone, and at other locations, it is within the flysch (Figure 4-17).

During ground reconnaissance, four locations were found where rock was exposed on either side of the fault. The exposures were observed at various intervals for over 8 km of the fault's length (Figure 4-17). The first site was about 1 km southwest of the village of Alevrada in a road cut located north of the road from Petrona to Alevrada (Location A, Figure 4-17). At this location, the main fault zone is within the flysch deposits in which siltstone on the south is brought into fault contact with fine-grained sandstone on the north. The fault contains a 90-cm-wide disturbed zone of clay gouge at both the outer contact with bedrock and the breccia in the central portion (Figure 4-18). The fault zone is oriented N40°E and is steeply dipping 80°NW to 83°SE. The south side of the fault has moved down with respect to the north side. This interpretation is based on down-dragged bedding on the northwest side of the fault and the orientation of breccia fragments within the fault zone whose long axes have a dip of 56 degrees to the south.

A second fault location within the Alevrada-Smardacha fault zone was observed approximately 0.5 km northeast of the location described above and may represent a continuation of the same fault trace (Location B, Figure 4-17). This fault zone is oriented N40°E, 83°SE. The fault is exposed on the southwest bank of a drainage ditch that is adjacent to a concrete spring box, northwest of the Petrona-Alevrada road and at the southwestern edge of the village of Alevrada. The fault contains a 25-cm-thick clay gouge zone with polished pebbles, the long axis of which is nearly vertical (Figure 4-19). The sense of



Locations approximate.
Not to scale.

EXPLANATION:

(A-E) Fault locations discussed in text

LOCATION MAP OF THE
ALEVRADA – SMARDACHA FAULT
Greece

Project No. 14087A
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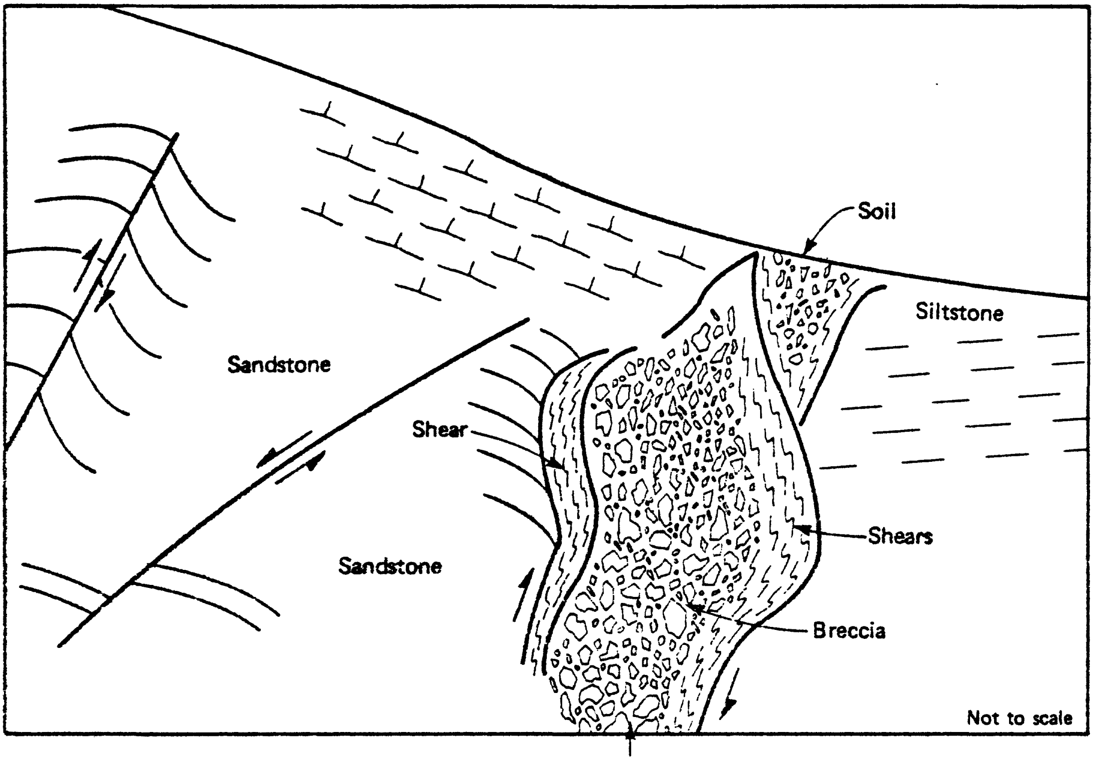
Figure 4-17

NORTHEAST VIEW*



Fault Strike N40°E
Dip 83°SE

NOTE:
* See Figure 4-17 for location.
Discussion in text refers to this as Location A on Figure 4-17.

FAULT WITHIN ALEVRADA–SMARDACHA
FAULT ZONE - LOCATION A
Greece

| | |
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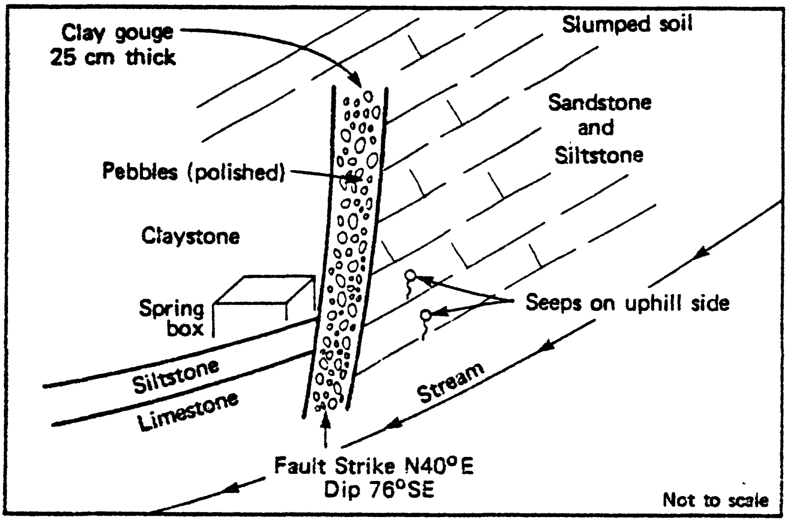
| Project No. 14087A | Figure 4–18 |
| **Woodward-Clyde Consultants** | Page 156 |

SOUTHWEST VIEW*



NOTE:

* See Figure 4-17 for location. Discussion in text refers to this as Location B on Figure 4-17.

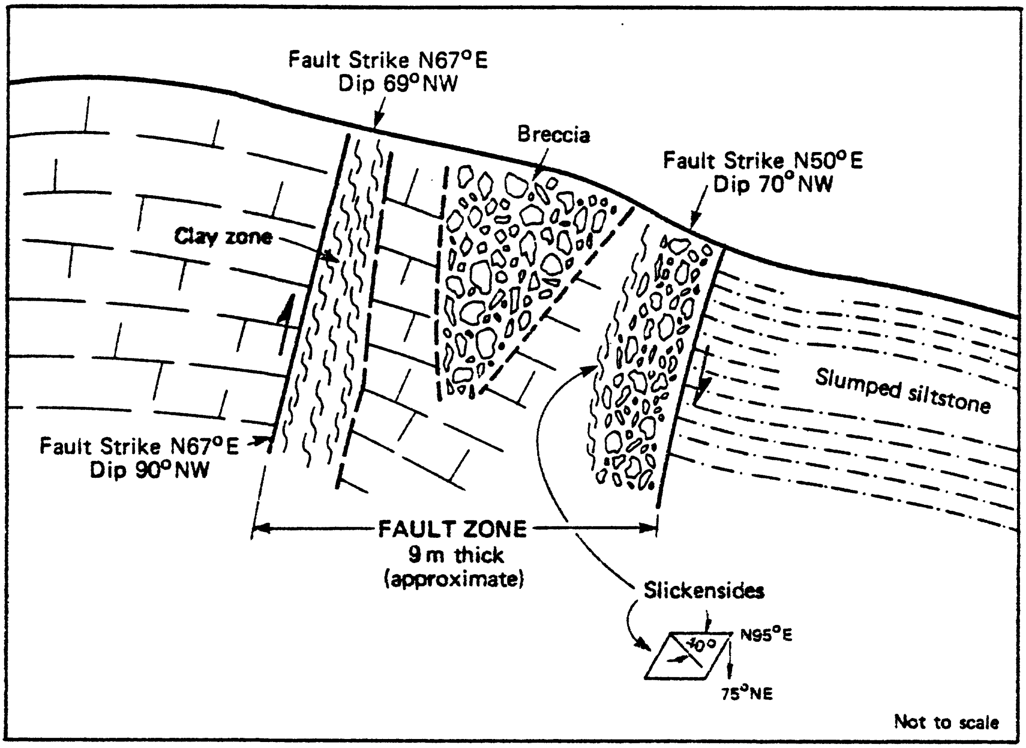
| FAULT WITHIN ALEVRADA–SMARDACHA FAULT ZONE – LOCATION B<br>Greece | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4-19<br>Page 157 |

displacement was not determined. Slumped soil covers the top of the fault, and seeps were found in both the sandstone and siltstone units on the north side of the fault.

The third location where the faulting was observed within the Alevrada-Smardacha fault zone was about 0.5 km northeast of the village of Alevrada, in a cut above the main dirt road leading northeast from the village. At this point, the fault zone is about 9 m wide (Figure 4-20) and has zones of more intense deformation on either side of the main fault zone. The most intensely sheared zone is at the southern edge of the exposure and is oriented N50°E, and dips 70°NW. This zone contains slickensided clay gouge, the slickensides dipping 40 degrees to the east. Crenulation folding is preserved in the clay gouge adjacent to linear shear planes that are slickensided and contain a clay filling 1 to 4 cm thick. The central part of the fault zone is composed of distorted bedding, breccia, and linear planes along which displacement has occurred. The northern edge of the exposure of the fault zone is marked by another clay zone similar to that at the southern edge, showing shearing and crenulation folding. This clay zone has an orientation of N67°E, 69°NW. Bending and drag on the adjacent beds outside the fault zone and rotated blocks within the fault zone show that the relative movement is north side up. Slumped talus and loose thin soil cover the fault zone on top of the cut.

Ground reconnaissance farther to the northeast of the village of Alevrada revealed a large rock and debris slide generally on line with the projection of the fault zone traced through the village (Location D, Figure 4-17). The large slide totally destroyed a lengthy section of road from Alevrada to Triklinos. The slide most likely occurred during the 1966 earthquake, based on reports from the villagers of Alevrada. These villagers also indicated that numerous slides and ground cracks occurred north and northeast of the village, as well as within the village,

NORTHEAST VIEW*



NOTE:

* See Figure 4-17 for location.
Discussion in text refers to this
as Location C on Figure 4-17.

| FAULT WITHIN ALEVRADA–SMARDACHA FAULT ZONE – LOCATION C<br>Greece | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4-20<br>Page 159 |

during the 1966 earthquake. Some houses were reported to have collapsed during the earthquake; however, most of the ground cracks and damage was reported to have occurred northeast of Alevrada. Four houses were reported to have been destroyed in one stream valley located about 1 km northeast of the village, and a crack about 15 cm wide and 10 m long was reported to have occurred near a house known as the Paleohoraki house. Other cracks were reported 3 km northeast of the village near a house known as the Pistiana house. Ground reconnaissance in the area where cracking was reported showed evidence of slumping, landsliding, and debris sliding. Because of the length of time since the earthquake, no cracks were observed and no conclusive evidence of surface rupture was observed.

The fourth fault location within the Alevrada-Smardacha fault zone is beneath the Smardacha Bridge (Location E, Figure 4-17) (Snow, 1971). Due to the general inaccessibility of this location and poor lighting conditions at the hour of this study, an examination of the location on the ground was not possible. However, during the aerial reconnaissance, the northern-most point of the Alevrada-Smardacha fault was observed to pass through this location. Snow (1971) reports an east-northeast trending, steeply dipping fault zone that contains slickensides dipping 45 degrees. From these data, he postulated normal displacement and dextral displacement that had displaced a fold axis for approximately 3 km along the fault.

From these five locations, as well as from observations made southwest of Alevrada, the Alevrada-Smardacha fault could be traced for approximately 15 km between the village of Petrona and the Smardacha Bridge. The sense of displacement is normal within the fault zone. Sinistral displacement was observed at one location (Location C, Figure 4-17), and dextral displacement was reported at another location (Location E, Figure 4-17) (Snow, 1971). This disparity may indicate recent displacement has had different components along the different segments or may indicate different segments of the fault have responded to different stress regimes. Although the fault passes into the western section of the reservoir, its relationship to seismic activity after impoundment of the reservoir remains unresolved.

During the investigation of the Alverada-Smardacha fault, the village of Alevrada, which consists of approximately 30 to 40 stone block houses, was examined in detail for evidence of ground cracking and/or building damage. No conclusive evidence of ground cracks were obtained, which may be due to the 12-year interval since the earthquake. Reconnaissance of the fault projection through Alevrada resulted in several locations where stone houses had fallen, leaving cement slab foundations. The collapse of these buildings as the result of the earthquake could not be verified. Two churches on the projection of the fault trace were apparently undamaged. An abandoned building in the northeast section of town had a caved-in roof and prominent cracks in the walls, but fire had severely damaged the building and the relationship of its damage to the earthquake is ambiguous.

During further ground reconnaissance in the village, a rather unique thick agglomerate debris slide deposit was noted behind one of the village churches, in the central-northern part of the village. At the church, one large spring, which supplies water for the village, has developed near the base of the agglomerate. The agglomerate was formed by debris slides from the adjacent high cliff of limestone to the northwest. The agglomerate has a lobe-shaped outline in plan view and a linear boundary at its lower edge. The outline of the scarp left by the limestone forming the agglomerate is visible on the limestone cliff. The agglomerate formed a fairly sharp linear 5- to 10-m high scarp. The alignment of this scarp is in a northeast direction, subparallel to, and about 100 m to the northwest of, the fault alignment (as defined by fault exposures). Rubble blocks of the coarse limestone agglomerate exist downslope from the scarp, but no part of the agglomerate deposit that looks in place was found downslope from the fault alignment.

From aerial reconnaissance of the agglomerate deposit, a clear outline of its extent is visible (Figure 4-21). Moreover, aerial reconnaissance helps define the zone as a series of linear elements marked by vegetational changes and topographic saddles and troughs. One possible explanation for the linear nature of the scarp is that it was fault-controlled, suggesting the faults have been active since the time of deposition of the agglomerate. Other similar subparallel linear elements, which may also be faults, were also noted.

### Triklinos Fault

The Triklinos fault crosses the Pindus thrust fault and the Alevrada-Smardacha fault. The first evidence of this high-angle, northwest-trending structure was noted while viewing the scarp of the Pindus thrust fault at the village of Paleohoria, in the eastern part of the reservoir (Location B, Figure 4-14). The Pindus fault scarp in this area is very linear and may be influenced by the Triklinos fault. An oblique aerial photograph on display in the Kremasta Dam power house shows a distinct northwest-trending linear feature in the same area where the fault was noted in the field. On the photograph, the structure was observed to extend northwestward from the Megdhoyas arm of the reservoir, across the drainage from Frangista, and toward the Agraphiotis arm of the reservoir.

During subsequent aerial reconnaissance of the Lake Kremasta reservoir area for this study, the linear feature noted on the oblique photograph and the scarp studied on the ground were observed to be approximately coincidental. This linear feature

View is to the northwest

AERIAL VIEW OF ALEVRADA–
SMARDACHA FAULT THROUGH
THE VILLAGE OF ALEVRADA
Greece

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 4-21

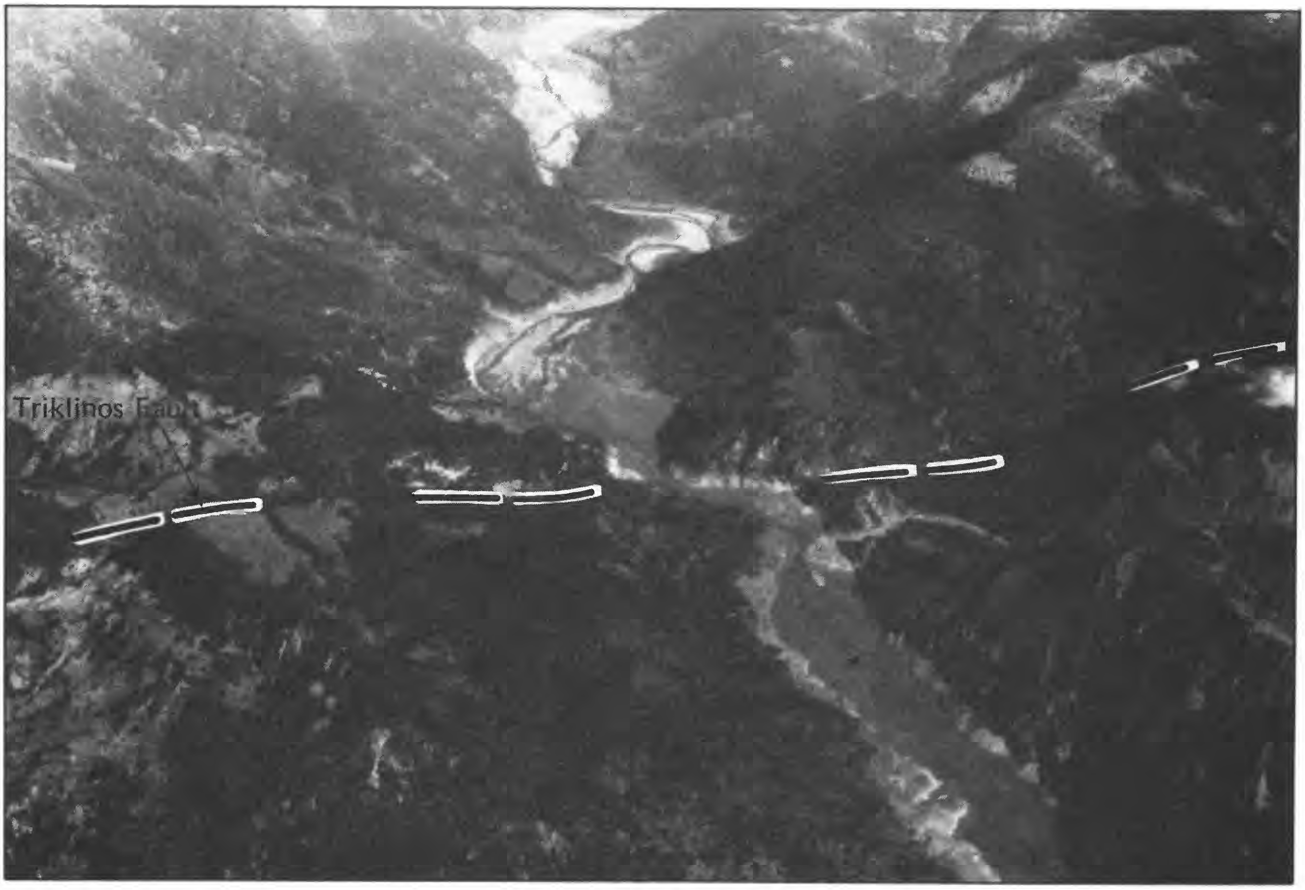
was observed to trend from the Megdhoyas arm of the reservoir, through the stream drainage from Frangista, which has had a sinistral displacement of approximately a hundred meters (Location D, Figure 4-14; Figure 4-22). The linear feature continues northwestward near the prominent scarp shown on Figure 4-15 and subparallel to the trend of the Pindus fault in this area of the lake region. Northwest of the village of Paleohoria, the Pindus thrust fault trends more northerly while the linear feature continues across the Acheloos arm of the reservoir and offsets the Alevrada-Smardacha fault with sinistral displacement (Location E, Figure 4-14; Figure 4-23). The linear trend was observed to continue northwestward to the village of Triklinos beyond which it could not be observed.

The Triklinos fault's observed length is at least 25 km. The fault trends northwest and is inferred to be active, based on the youthful nature of the displaced Frangista drainage. Recurring displacement within the present tectonic stress regime has been inferred to have occurred, resulting in the offset drainage of the stream. The trend of the fault and the sense of displacment agree remarkably well with that postulated by Comninakis and others (1968) (Figure 4-10). Correlation of the field observations and the seismologic calculations is not possible at the present time, but the similarity is notable.

SUMMARY AND CONCLUSIONS

1) Faulting is prevalent in the Kremasta reservoir area.

2) The Pindus thrust fault displaces Miocene sedimentary strata and passes through the reservoir area. The time of latest displacement along this fault could not be determined.



View is to the north.

AERIAL VIEW OF SINISTRAL DISPLACEMENT OF FRANGISTA STREAM DRAINAGE AT TRIKLINOS FAULT
Greece

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| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4-22 |
| | |

View is to the west.

| AERIAL VIEW OF SINISTRAL DISPLACEMENT OF THE ALEVRADA-SMARDACHA FAULT BY THE TRIKLINOS FAULT<br>Greece | |
|---|---|
| Project No. 14087A | Figure 4-23 |
| **Woodward-Clyde Consultants** | Page 166 |

3) The Paleohoria fault is a northeast-trending, high-angle fault whose regional extent was not determined. Displacement is up to the northwest. Field data suggest the more recent movement may be dextral and reverse. The fault is located in the eastern part of Lake Kremasta, and its trace projects through the Megdhoyas arm of the lake. Circumstantial evidence, including a topographic scarp and slickensides, suggests that it may be active.

4) The Alevrada-Smardacha fault is a prominent northeast-southwest trending, high-angle fault of at least 15 km length between Petrona and the Smardacha Bridge. Normal displacement down to the southeast was observed, as was sinistral and dextral displacement. Extensive landsliding occurred north of the village of Alevrada during the 1966 earthquake. The landslides apparently were triggered by the earthquake. No ground cracks were identified along the Alevrada-Smardacha fault in the Alevrada area. Clear topographic features and recent seismicity suggest this fault may be active.

5) The Triklinos fault is a northwest-trending, high-angle fault whose observed length is at least 25 km from the Megdhoyas arm of Lake Kremasta to the village of Triklinos. An offset stream drainage and offset of the Alevrada-Smardacha fault show sinistral displacement of approximately a hundred meters. The youthful nature of the displaced stream demonstrates the recency of fault displacement along this feature and strongly suggests the fault is active.

6) The Triklinos fault is approximately parallel to, and very near, the fault on which the 1966 earthquake (M = 6.3) was postulated to have occurred by Comninakis and others (1968). The sense of displacement is also the same.

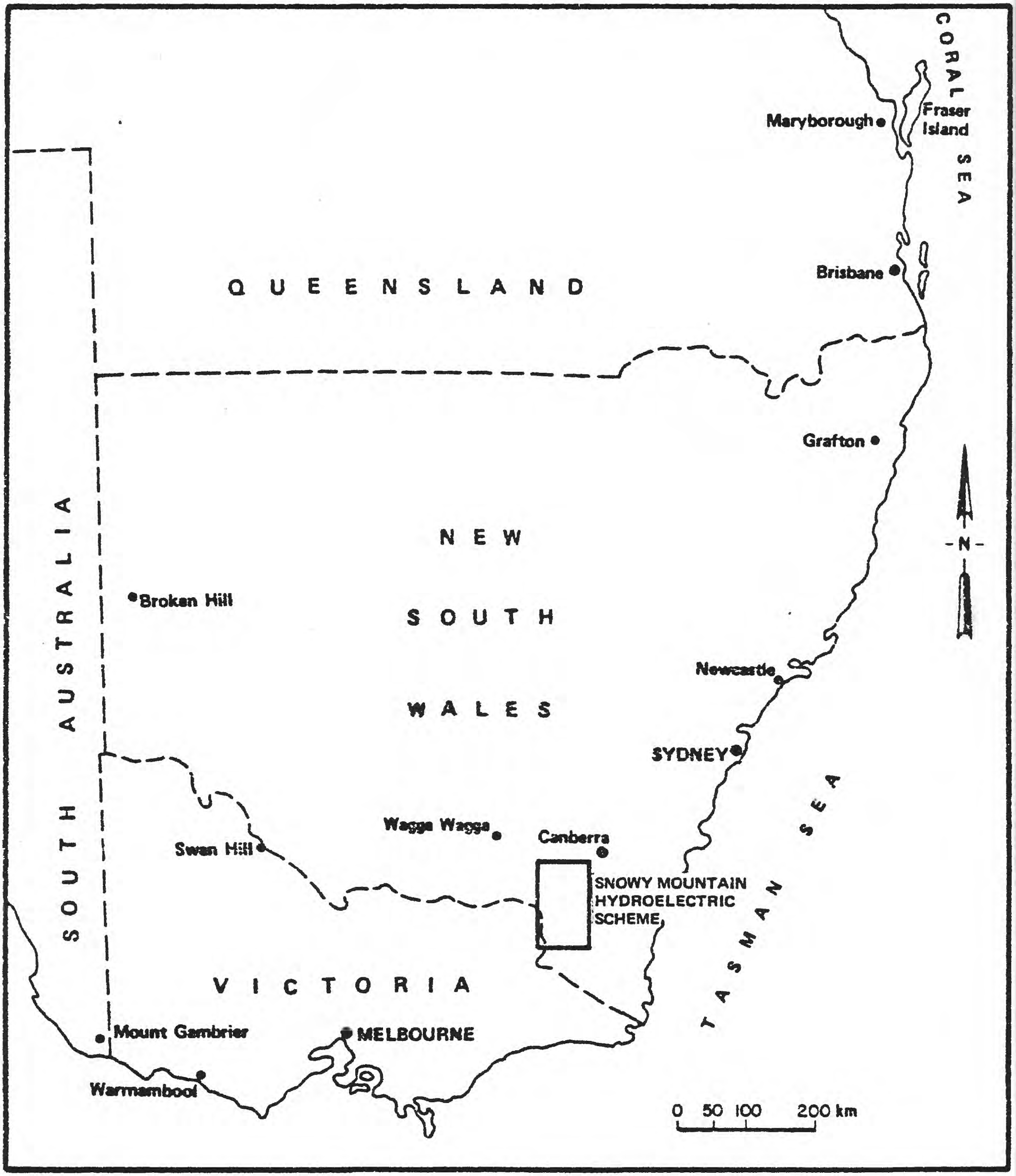
7) Active faults, including the Triklinos fault and possibly the Alevrada-Smardacha fault and the Paleohoria fault, are present within the hydrologic regime of Lake Kremasta.

## 4.4 EUCUMBENE, TALBINGO, AND BLOWERING RESERVOIRS, AUSTRALIA

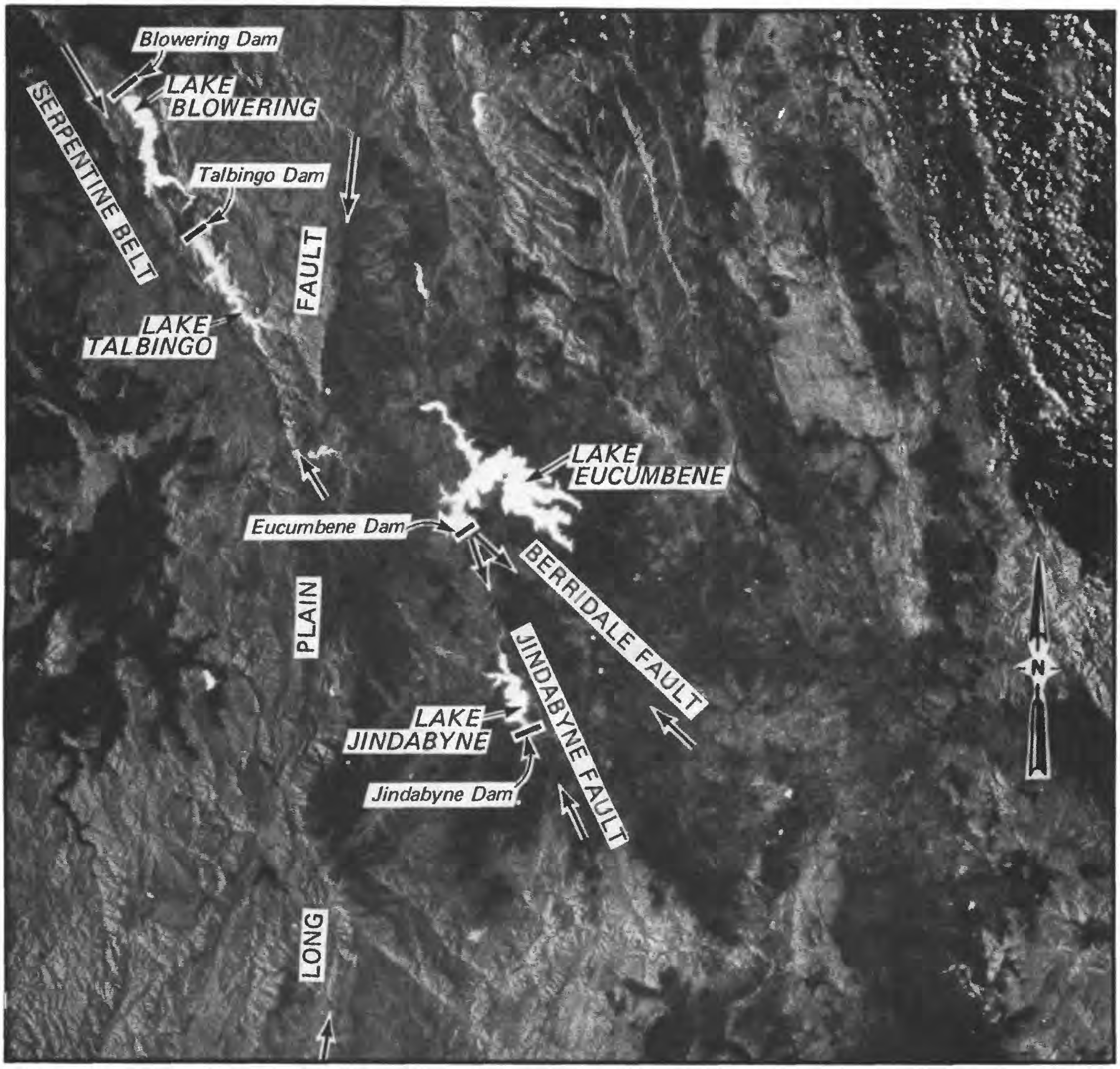
### INTRODUCTION

Lakes Eucumbene, Talbingo, and Blowering are the largest reservoirs in the Snowy Mountain Scheme, a hydroelectric and irrigation complex located in southeastern Australia (Figure 4-24). These lakes are formed by the impoundment of the Snowy and Eucumbene Rivers which are diverted through a series of tunnels to the Murray and Murrumbidgee Rivers (Figure 4-25). The characteristics of each reservoir are presented in Table 4-2, and a photograph of Eucumbene Dam is shown in Figure 4-26.

Initial impoundment of Lakes Eucumbene and Talbingo were accompanied by high levels of seismic activity that appear to be related to the reservoir filling. No unusual seismic activity was recorded during impoundment of Lake Blowering, which is immediately downstream from Lake Talbingo and which was impounded two years earlier than Lake Talbingo. A preliminary study was undertaken to evaluate fault activity within the regime of these reservoirs. For the purposes of this study, a fault is defined as active if it has had displacement during that area's present stress regime.



| PROJECT LOCATION MAP<br>LAKES EUCUMBENE, TALBINGO,<br>AND BLOWERING<br>New South Wales, Australia | |
|---|---|
| Project No. 14087A<br>Woodward-Clyde Consultants | Figure 4-24<br>Page 170 |



PROJECT AREA
LAKES EUCUMBENE, TALBINGO, AND BLOWERING
New South Wales, Australia

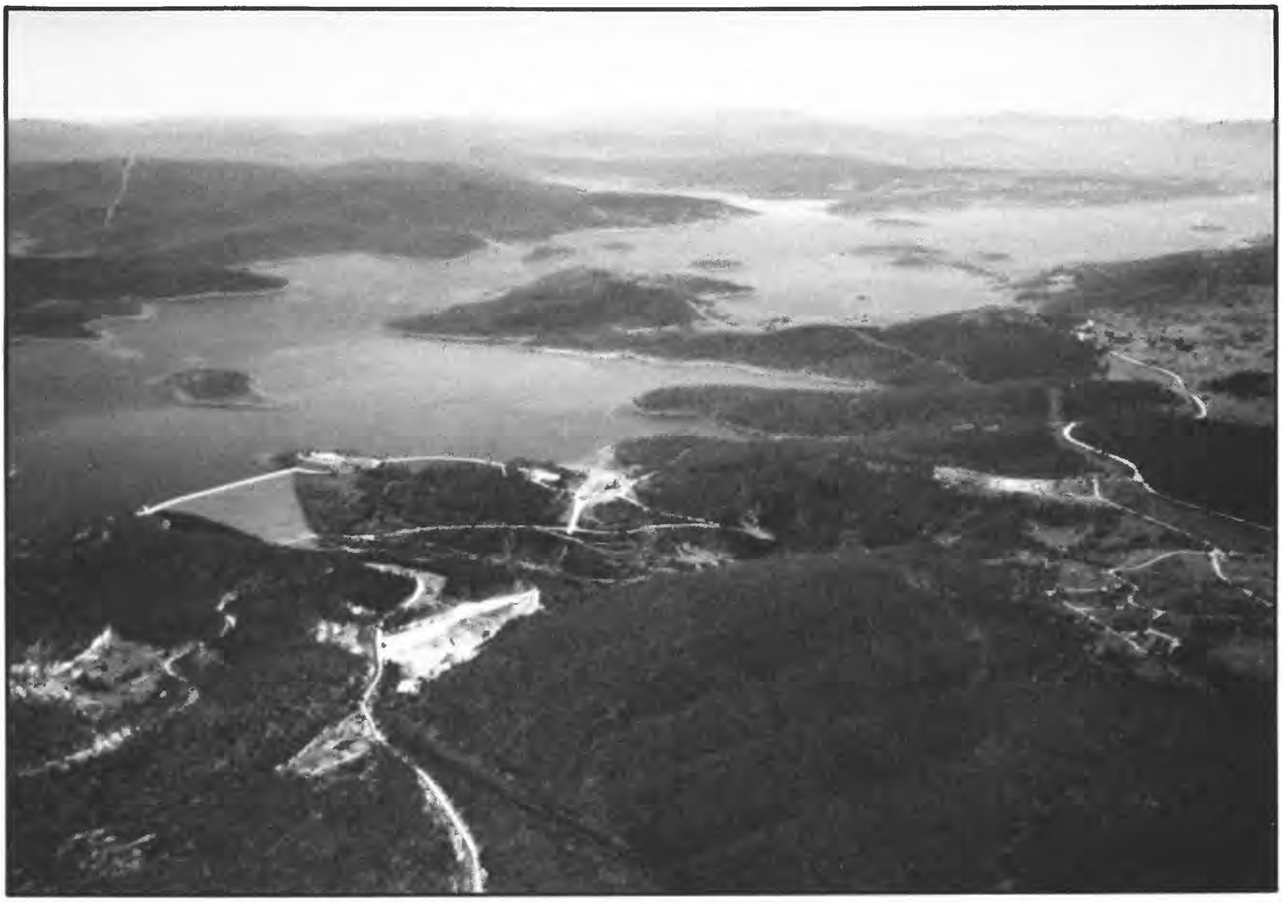
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4-25<br>Page 171 |
|---|---|

TABLE 4-2
DESCRIPTION OF THE EUCUMBENE, TALBINGO, AND BLOWERING RESERVOIRS

| | Eucumbene | Talbingo | Blowering |
|---|---|---|---|
| Type | Earth/Rock | Earth/Rock | Earth/Rock |
| Water Depth | 106 m | 142 m | 95 m |
| Crest Length | 579 m | 700 m | 888 m |
| Reservoir Area | 145 $km^2$ | 19.4 $km^2$ | 44.5 $km^2$ |
| Gross Storage | 4761 x $10^6$ $m^3$ | 935 x $10^6$ $m^3$ | 1628 x $10^6$ $m^3$ |
| Date Completed | May 1958 | October 1970 | September 1968 |
| Foundation Rock | siltstone and quartzite | rhyolite lava and tuff | quartzite, metasiltstone, phyllite |

The scope of work for this study consisted of the following:

- gathering and review of published and unpublished data and maps;
- discussions with scientists resident in, or familiar with, the study areas;
- aerial reconnaissance flights over the study area;
- ground reconnaissance at selected locations in the study area;
- examination of aerial photographs of portions of the study area;
- collecting and evaluation of seismologic data.



View is to the northeast, across Lake Eucumbene. Eucumbene Dam is in foreground.

EUCUMBENE DAM AND
LAKE EUCUMBENE

New South Wales, Australia

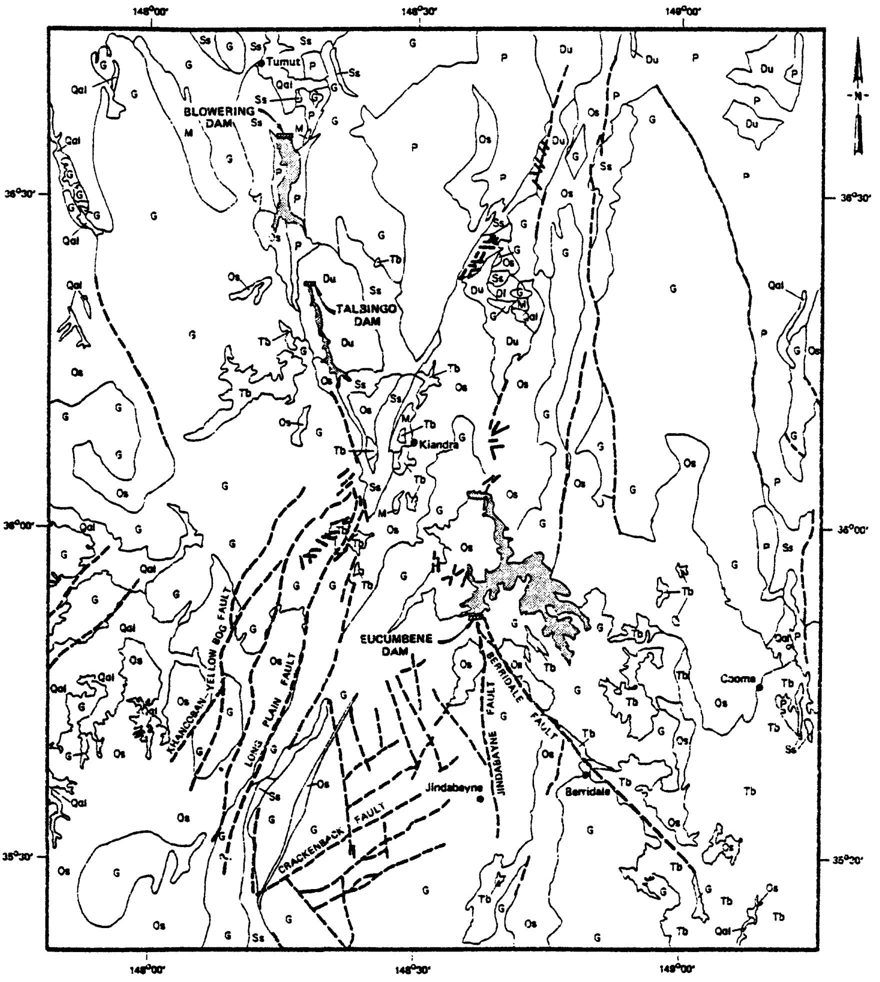
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4-26<br>Page 173 |
|---|---|

The initial portion of the data gathering effort used Woodward-Clyde Consultants' library facilities and files in San Francisco. Additional data and maps were obtained from state and federal government agencies in Sydney, Canberra, and Cooma, Australia. Selected references also were reviewed in the library of the Geological Survey of New South Wales. Seismologic data were requested from the Research School of Physical Sciences of the Australian National University. Data on reservoir filling histories were solicited from the Snowy Mountains Hydro-Electric Authority. Topographic maps and photographs were obtained from the Department of Public Lands in Sydney and Canberra, Australia.

## REGIONAL GEOLOGIC SETTING

The major portion of the Snowy Mountains area is underlain by granitic and gneissic rock of Silurian to early Devonian age. Most of remainder of the area is underlain by highly folded metasediments and metavolcanics of Ordovician and Silurian age, and by less-folded sedimentary and volcanic rocks of Devonian age. Relatively flat-lying Tertiary basalt flows cap the older rocks in some of the higher plateaus; these flows directly overlie unconsolidated river and lake deposits in portions of the area. Alluvial deposits and glacial deposits are present locally. The regional geologic relationships are shown in Figure 4-27.

At Eucumbene reservoir, according to mapping by White and others (1977), a major portion of the lake and much of the adjoining area to the north, east and west, are underlain by black shale, chert, sandstone, and slate of late Ordovician and early Silurian age. These rocks are strongly weathered to decomposed where exposed. In the southern portion of the Eucumbene reservoir area, and locally elsewhere, these rocks are intruded by granodiorite of late Silurian or early



0 5 10 15 20 25 30 km

EXPLANATION:

| | |
|---|---|
| Qal | Quaternary alluvium |
| Tb | Tertiary basalt flows |
| Du | Devonian undifferentiated, includes rhyolite, dacite, conglomerate, sandstone, shale, tuff, limestone |
| Dl | Devonian limestone |
| Ss | Silurian shale, siltstone, sandstone, limestone, tuff |
| Os | Ordovician shale, slate, schist, minor siltstone, quartzite, chert, andesite, tuff |
| G | Granitic rocks, including granite, granodiorite, granitic gneiss, gneiss |
| P | Porphyry |
| M | Monzonite, diorite, norite, basic rocks |
| S | Serpentine and associated rocks |
| ——— | Geologic contact |
| — — — | Fault |

Source:

Modified from Snowy Mountains Hydroelectric Authority, Seismic Map of the Snowy Mountains Area, and Geological Survey of New South Wales, Berridale Sheet (1976).

REGIONAL GEOLOGY
LAKES EUCUMBENE, TALBINGO, AND BLOWERING
New South Wales, Australia

Project No. 14195C

**Woodward-Clyde Consultants**

Figure 4-27

Devonian age. The granodiorite is overlain locally by basalt of Tertiary age, which is the youngest mapped geologic unit in the area. Unconsolidated deposits of Quaternary age are present but appear to be thin and of very limited areal extent.

At the Talbingo reservoir, the results of reconnaissance mapping by the Geological Survey of New South Wales (Adamson, 1955) indicate that this reservoir is underlain principally by volcanics and closely interrelated sedimentary rocks of Devonian age. Mapping by Brunker and others (1970) indicates that the southern end of the reservoir overlaps greywacke, siltstone, quartzite, tuff, and conglomerate of upper Silurian age. Brunker and others (1970) also show that at least one arm of the reservoir extends across serpentinite and related rocks that have been inferred to represent oceanic lithosphere of the Cowra Trough (Degeling, 1977). This overlapping of the serpentinite by the reservoir was confirmed during the field studies for this report. This band of serpentinite and related rock projects toward Lake Blowering but is mapped as pinching out approximately 6 km south of the Blowering Reservoir (Brunker and others, 1970). In addition, a prominent lineament associated with the serpentinite extends northward, subparallel to Blowering reservoir.

The Blowering reservoir area, as mapped by Brunker and others (1970), (1970), is underlain principally by quartz feldspar porphyry of upper Silurian age and by associated slate greywacke, sandstone, quartzite, tuff, and andesite. These units are closely interbedded. Similar rocks of early Silurian age are also mapped as being present beneath the southwestern arm of the reservoir.

The Snowy Mountains region is traversed by numerous faults, many of which may have developed concurrently with the older stages of folding. Other faults are much younger and are believed to have been associated with uplift and warping that took place during Tertiary time. Complex block-faulting is particularly evident throughout much of the Snowy Mountains Region. These faults are visible as a system of intersecting lineaments, the most prominent of which has a north-northwest trend and the other has a northeast trend (Figures 4-25 and 4-27) (Moye and others, 1963; Maffi and Simpson, 1977).

The block faulting appears to be superimposed on an older tectonic trend, as delineated on various maps published by the Geological Survey of New South Wales (Pogson, 1972; Barnes and Herzberger, 1975; Brunker and others, 1970; Degeling, 1977). This older trend consists of a belt of thrust faults that separates rock of significantly different type and age. In the vicinity of Talbingo reservoir, serpentinite and ultrabasic igneous rocks, inferred to represent oceanic upper mantle of late Ordovician to early Silurian age (Degeling, 1977), are exposed in a linear north-northwesterly trend that forms a "Y" junction with the main northeasterly trend of thrust faults (the Long Plain fault on Figure 4-27). Talbingo and Blowering reservoirs are both located within the "Y", and Talbingo locally overlies one arm of the "Y".

Left-lateral wrench faults also have been mapped in the Snowy Mountains area and include the Berridale fault, which is located near Lake Eucumbene (Figure 4-27) (White and others, 1977). In addition, a major thrust fault (the Jindabyne fault on Figure 4-27), is located in the immediate vicinity of Lake Eucembene.

## REGIONAL SEISMIC ACTIVITY

The historical seismicity for the Snowy Mountains area is presented on Figure 4-28. This information was obtained

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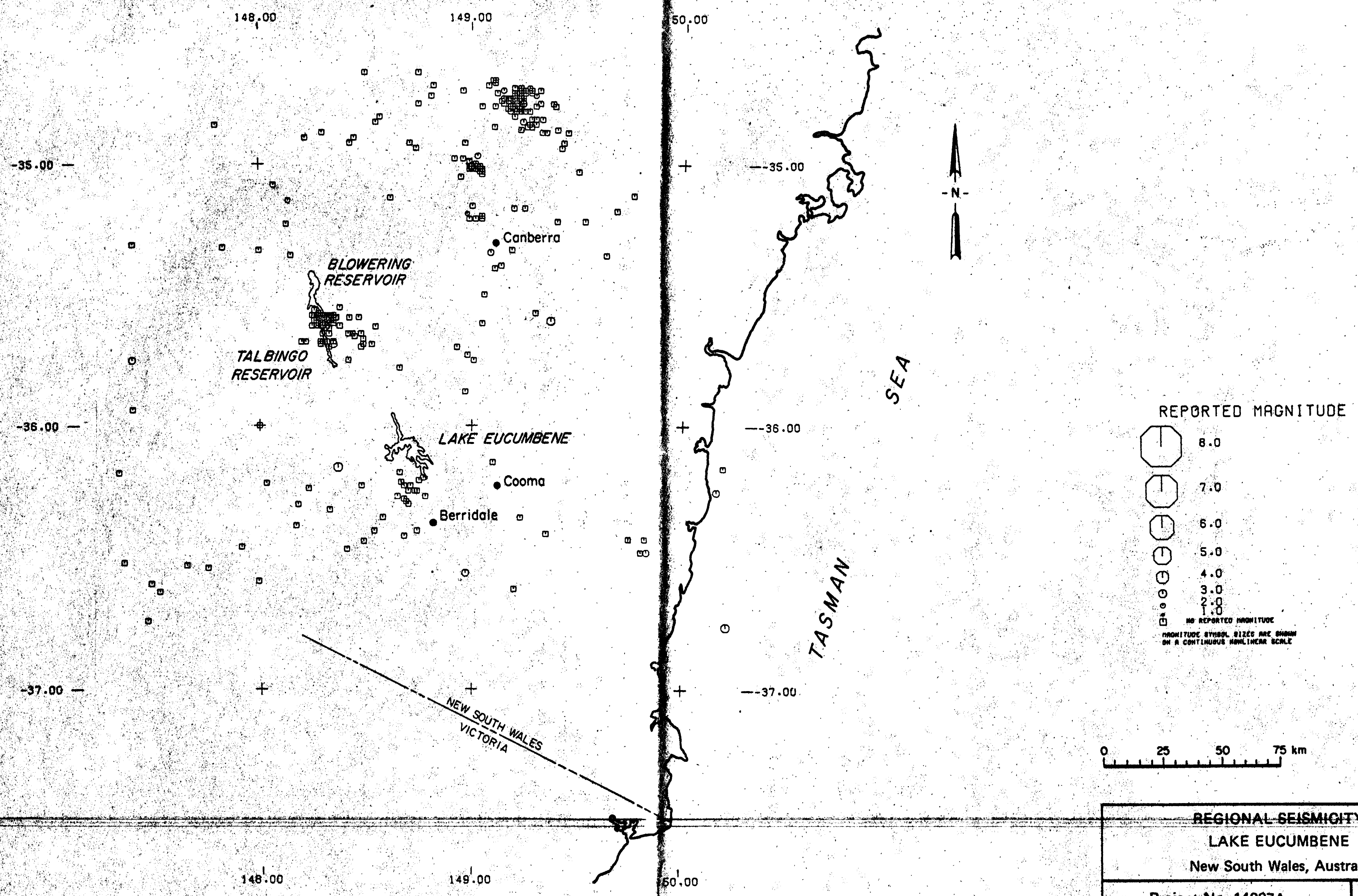


**REGIONAL SEISMICITY**
LAKE EUCUMBENE
New South Wales, Australia

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 4-28

principally from the Snowy Mountains Hydro-Electric Authority and was based on data from a seismograph network established in 1957. Originally, this network consisted of four stations, each with a recorder, and was designed with the intent of ensuring detection and location of microearthquakes and larger seismic events. The data collected by the network are now telemetered directly to a recorder at the Australian National University in Canberra.

Lake Eucumbene

Impoundment of Lake Eucumbene began in June 1957, prior to establishment of the Snowy Mountains seismographic network. The pre-existing seismograph network was not capable of detecting events with magnitude less than 4 in the Snowy Mountains region. Thus, a good pre-impoundment data base is not available. However, a large body of seismic data has been accumulated since impoundment. Forty-four earthquakes of sufficient magnitude to be located accurately occurred during a 3-1/2 year period from 1958 to 1962 in a region located generally south to southeast of the reservoir (Figure 4-28). The largest of these events, which occurred near the community of Berridale in May 1959, had a magnitude of 5. Twenty-one minor shocks occurred in the vicinity of this magnitude 5 event, and they are reported to have the strain release pattern of a typical aftershock sequence. These shocks were relatively distant from the reservoir.

At the time of the main Berridale event, Lake Eucumbene had not yet reached the dead volume of approximately 432 x $10^6$ $m^3$; ponding of the live storage began in October 1958. Cleary and others (1964) interpret this as evidence that reservoir impoundment could not have been responsible. However, in comparison, Lake Mendocino in California, which has a total storage capacity of only 151 x $10^6$ $m^3$, is a well-documented probable source of reservoir induced seismicity (Toppozada and Cramer, 1978). Lake Marathon in Greece, which has a capacity of only 41 x $10^6$ $m^3$, is another documented probable source of reservoir induced seismicity (Gupta and Rastogi, 1976).

Fault-plane analysis of the Berridale earthquake suggests that the event originated on either a high-angle reverse fault with a strike of about N50°W degrees, or a low-angle, south- or southeast-dipping reverse fault with a possible range of strikes between N40°W degrees and east-west (Cleary and others, 1964). The first solution, which suggests a high-angle reverse fault parallel to the Crackenback escarpment, was selected as correct by Cleary and others (1964). However, the results of recent geologic mapping (White and others, 1977) indicate that the Crackenback fault does not extend east of Lake Jindabyne. Moreover, the earthquake epicenters, as plotted, do not line up along the Crackenback fault. In fact, they are so widely scattered that selected groups could be attributed to the Jindabyne fault, the Berridale fault, and to a number of minor faults in the area between Berridale and Lake Eucumbene. Therefore, the alternative solution (involving a northeast or east-west trending, low-angle thrust fault) warrants further consideration. This solution would represent a plane subparallel to the Khancoban-Yellow Bog fault system in which bedrock has been thrust over Pleistocene(?) or more recent river gravels. This fault system appears to be related to the Long Plain fault, which is the most prominently visible structural feature on satellite imagery of the area (Figure 4-25).

Lake Talbingo

Lake Talbingo was outside the quadrangle of the original seismograph network, but a station was added in 1969, two years prior to filling. The additional station made it possible to locate events with magnitudes of 1 or less in this area. Prior to 1 May 1971, when filling began, seismic activity had been monitored for 13 years, including two years of nearby monitoring by the Talbingo station. The only earthquake recorded during that period was a minor one located about 19 km north of the dam site. Increased seismic activity commenced on 19 May 1971 with a small event and was followed by two more small earthquakes during May. The activity in June increased to 39 recorded events, of which four were of sufficient magnitude to be located (maximum magnitude recorded was 2.4). In July and August, an average of 20 locatable events per month occurred as reservoir filling continued. The rate of filling dropped sharply after August, and there was a correspondingly sharp decrease in the number of locatable events. However, the number of microearthquakes remained fairly constant, initially at several hundred per month (Timmel and Simpson, 1972). The locations of the larger earthquakes are shown on Figure 4-28).

Lake Blowering

Located immediately downstream from Talbingo Dam (Figure 4-25), the Blowering reservoir essentially has the same pre-impoundment seismic history as that described above for Lake Talbingo. During the 16-month period following impoundment, one microearthquake was located within 1 km of the reservoir.

FAULT INVESTIGATION

Lake Eucumbene Area

The geologic maps of the Lake Eucumbene area indicate that two faults, the Berridale wrench fault and the Jindabyne thrust fault, converge toward the Eucumbene Dam and that their joint continuation may extend beneath the reservoir (Figure 4-27). These features were examined during the field reconnaissance studies.

Berridale Wrench Fault - The Berridale wrench fault is a major northwest-trending feature described in the literature as exhibiting approximately 11 km of left-lateral offset and as showing evidence of vertical displacement (Lambert and White, 1965; White and others, 1977). The left-lateral displacement is believed to have occurred during the Devonian period, whereas the inferred vertical displacement apparently has offset basalts of Tertiary age. Clear evidence of this displacement was not observed during field reconnaissance conducted for the study. However, during aerial reconnaissance, the Berridale fault was recognizable on the basis of linear tonal changes in grassy areas, gross changes in vegetation, linear sidehill depressions, and aligned saddles (Figure 4-29).

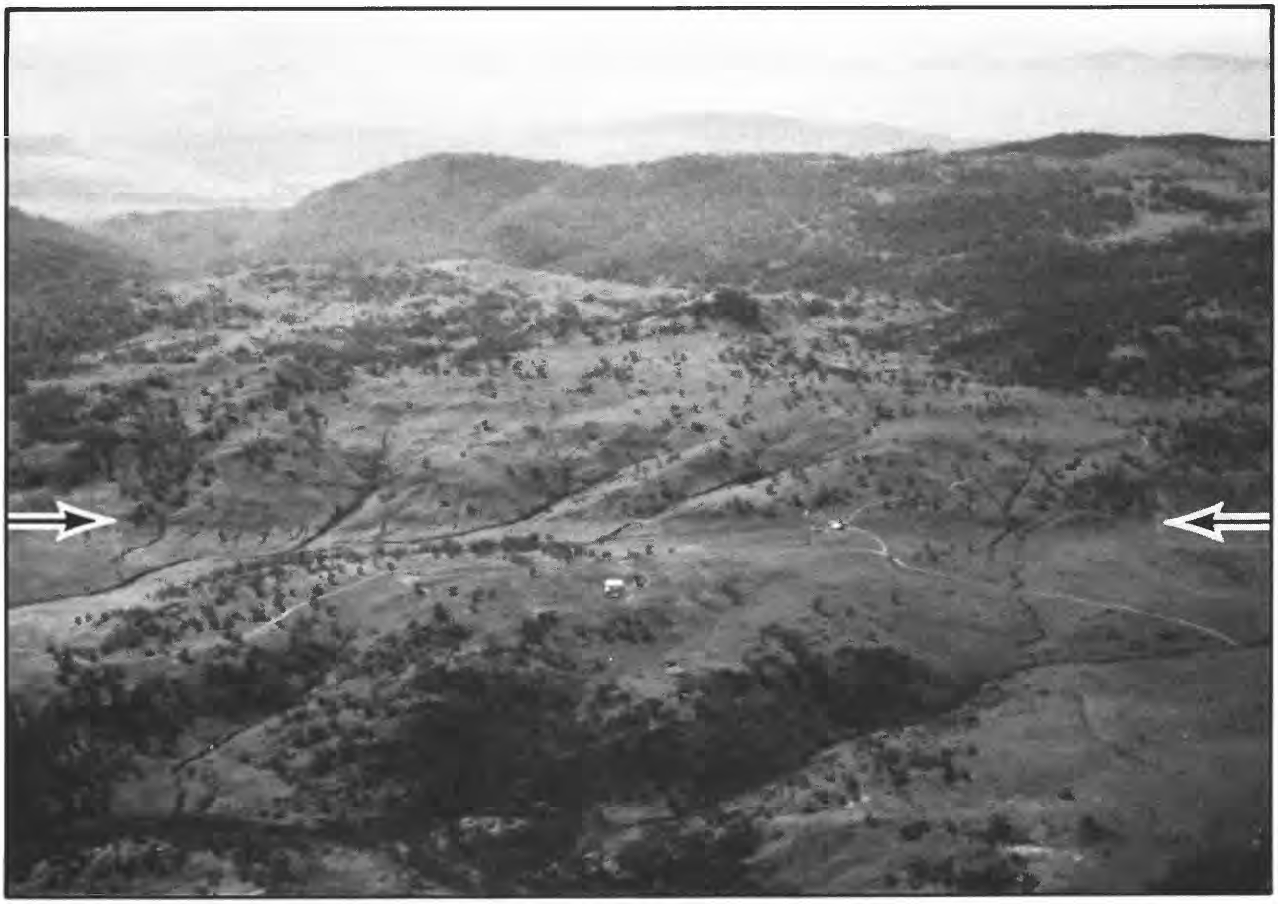
Lambert and White (1965) state that the Berridale fault has produced linear scarps in alluvium southeast of Berridale, where the current reconnaissance started. They also show an aftershock sequence in the Berridale area as having a northwest-striking, left-lateral, stike-slip component. Thus, on the basis of stratigraphic, geomorphic, and seismic evidence, the Berridale fault was classified as active for the purposes of this study.

Jindabyne Thrust Fault - The Berridale fault appears to join the north-trending Jindabyne thrust fault immediately south of Eucumbene Dam (Figure 4-27). White and others (1976) state that the Jindabyne fault is marked by a prominent scarp over much of its mapped length (Figure 4-30), and they infer that this fault was a factor in impounding the postulated Pleistocene-aged Lake Jindabyne. White and others (1976) also

View is to the northeast. Arrows denote break in slope along Berridale fault.

BERRIDALE WRENCH FAULT
VICINITY OF LAKE EUCUMBENE
New South Wales, Australia

| | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4-29 |
| | |



View is to the east, across Jindabyne fault near Hollins Crossing. The prominent topographic expression is shown.

| JINDABYNE THRUST FAULT<br>VICINITY OF LAKE EUCUMBENE<br>New South Wales, Australia | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4-30<br>Page 184 |

point out that all faults mapped east and west of the Jindabyne fault are terminated by this fault. White and others (1976) identify a recent uplift along the Crackenback and Mowamba faults, both of which join or are cut off by the Jindabyne fault. The structural picture of the region, therefore, can best be explained as the Jindabyne fault being contemporaneous with the strike-slip faulting and having absorbed all the strike-slip displacement.

During the field reconnaissance for the current study, the mapped trace of the Jindabyne fault was observed as characterized by alignments of linearly grooved saddles, vegetational changes, and springs. For the purposes of this study, the Jindabyne fault is considered active, based upon the structural relationships.

Lake Talbingo and Blowering Areas

Long Plain Fault - Talbingo reservoir is located at the juncture of a "Y" that is formed by a splay in a major tectonic feature that could be construed to represent a fossil plate boundary (Figure 4-27). For the purposes of this report, this major tectonic line will be referred to as the Long Plain fault. (This nomenclature has been used previously by Maffi and Simpson, 1977.) This feature, which is shown on numerous geologic maps of the area (Pogson, 1972; Barnes and Herzberger, 1975; Brunker and others, 1970; and Degeling, 1977), extends southeastward into Victoria. In the project area, the Long Plain fault forms a dividing line between the Devonian-aged rock of the Kosciusko Plateau and Silurian- and Ordovician-aged rocks to the northwest (Figure 4-27). It is bordered by a broad zone of block faults and thrust faults. In the vicinity of Talbingo reservoir, this fault is characterized in part by the presence of a linearly extensive band of serpentinite and ultrabasic igneous rocks in a series of outcrops that are prominently visible from the air.

Individual faults within or evidently closely related to this system have been inferred to have been reactivated in post-mid-Tertiary time. K. R. Sharp of the Snowy Mountains Engineering Corporation (personal communication, 1978) cites as evidence of this reactivation thrusting of bedrock over gravel along the Khancoban-Yellow Bog fault in the Khancoban area (Figure 4-31) and a 125-m scarp that is across the Long Plain fault in 20 million-year-old basalt near Tumut Pond. He also cites extraordinarily deep accumulations of post-mid-Tertiary warping, or "tectonic ponding," that could be construed to suggest activity of faults along the major tectonic line. Gill and Sharp (1956) cite data establishing the age of the Kiandra deposits as Tertiary. However, the gravels at Khancoban are in a currently active river valley and may represent Pleistocene or younger deposition. Unfortunately, the exposure exhibiting bedrock thrust over gravel has become overgrown since the visit by Sharp, and it could not be located during the recent field studies. One road cut exhibiting evidence suggestive of thrusting of decomposed granite over gravels was observed near Khancoban, but the evidence was equivocable.

An unmapped feature that may represent an active branch of the Long Plain fault is present near the shore of Blowering reservoir. This feature is identifiable from the air on the basis of an alignment of linear depressions, saddles, and blocked or offset drainages. For the purposes of this study, the geomorphic and structural relationships along faults associated with the Long Plain fault have been considered to be evidence of fault activity during the active tectonic regime.

Bedrock thrust over gravel, vicinity of Khancoban. Photograph courtesy of Mr. Kenneth R. Sharp, Snowy Mountain Engineering Corporation, Cooma, N.S.W., Australia

| KHANCOBAN-YELLOW BOG FAULT<br>SNOWY MOUNTAINS<br>New South Wales, Australia | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4–31<br>Page 187 |

# CONCLUSIONS

## Lake Eucumbene

The most extensive faults to which earthquakes in the Lake Eucumbene area could be attributed are the Jindabyne and Berridale faults. The mapped geologic relationships and geomorphic features observed during the aerial and field reconnaissance for the present study indicate that these faults are relatively young or have had a history of activity that has continued into late Cenozoic time.

## Lakes Talbingo and Blowering

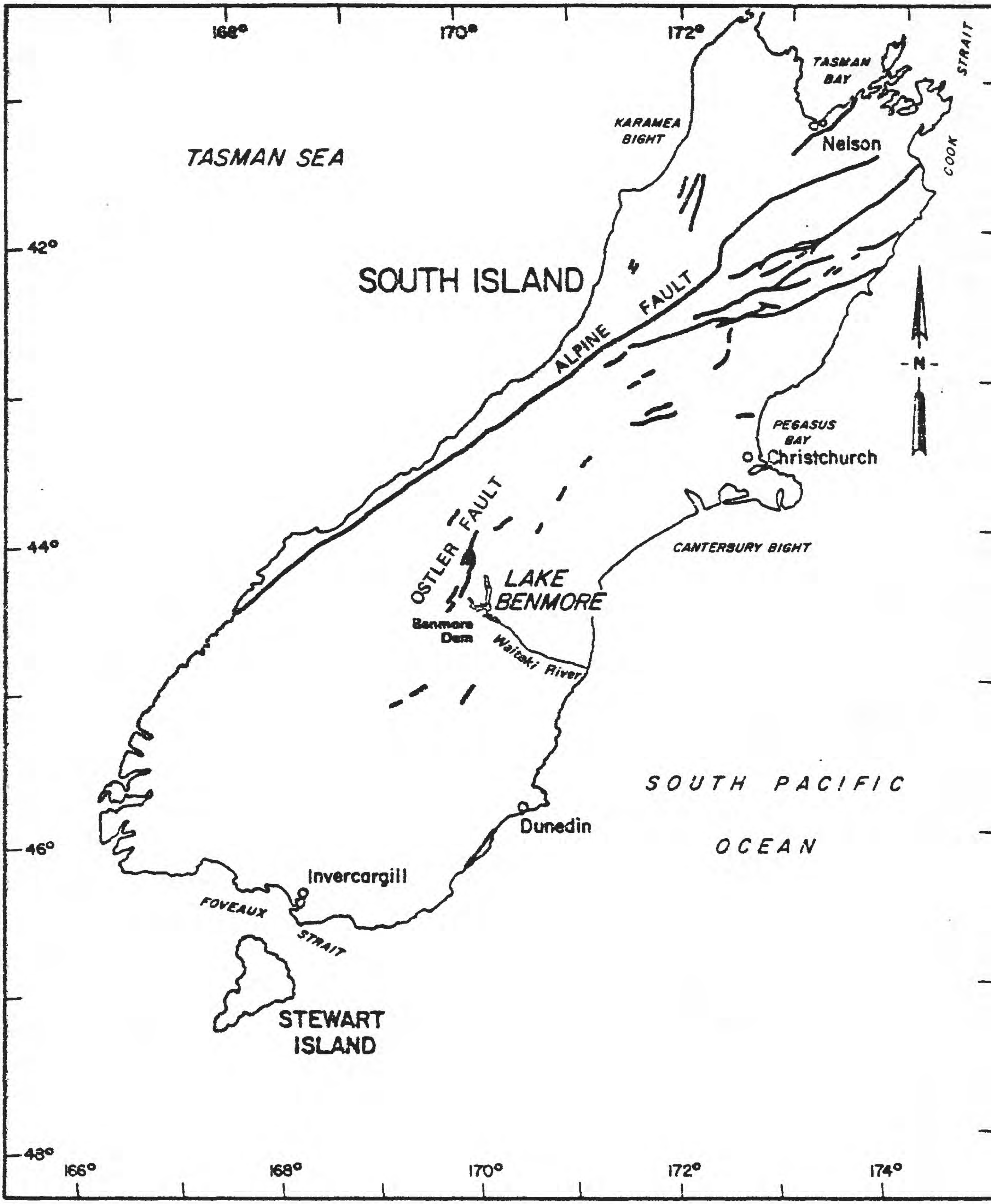
The seismic activity associated with the filling of Lake Talbingo may be related to faults associated with the Long Plain fault in the Lakes Talbingo and Blowering area. On the basis of the geomorphic evidence along these faults, and evidence of thrusting of bedrock over Pleistocene(?) or younger gravel along the Khancoban-Yellow Bog fault in the Khancoban area, these faults have been considered active.

## 4.5 LAKE BENMORE, NEW ZEALAND

### INTRODUCTION

Benmore Dam impounds the Waitaki River and its six tributaries, forming Lake Benmore, the largest man-made lake in New Zealand (Figures 4-32, 4-33, and 4-34; Table 4-3). Lake Benmore, located in the central portion of South Island (Figure 4-32), is a key feature of the Upper and Middle Waitaki Power Scheme. Two other large reservoirs, Lakes Pukaki and Ohau, are located on the headwaters of the Waitaki River within 25 km of Lake Benmore, and a third, Lake Tekapo, lies within 50 km of Lake Benmore (Figure 4-33). These three reservoirs were natural lakes that have been modified to serve as reservoirs.

After impoundment of Lake Benmore in 1964, seismicity within 80 km of Benmore Dam (including the area of the three subsidiary reservoirs) increased three to six times over the pre-impoundment seismicity (Adams, 1974). Because of this increase in seismicity upon the impoundment of Lake Benmore, a preliminary study was undertaken to evaluate if active faults are present within the influence of Lake Benmore. For the purposes of this study, a fault is defined as active if displacement has occurred during that area's present stress regime. For the Lake Benmore area, this would be Late Cenozoic time.



EXPLANATION:

Active Fault

0 20 40 60 80 100 km

LOCATION MAP OF LAKE BENMORE

South Island, New Zealand

| Project No. 14087A | Figure 4–32 |
|---|---|
| Woodward-Clyde Consultants | Page 190 |

| PROJECT AREA<br>LAKE BENMORE<br>South Island, New Zealand | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4–33<br>Page 191 |

View is to the north, across Lake Benmore: Benmore Dam is in foreground and Lake Pukaki in distance.

| BENMORE DAM AND LAKE BENMORE South Island, New Zealand | |
| --- | --- |
| Project No. 14087A **Woodward-Clyde Consultants** | Figure 4–34 |
| | |

TABLE 4-3
DESCRIPTION OF THE
BENMORE DAM AND RESERVOIR

| | |
|---|---|
| Type | Earthfill |
| Structural Height | 110 m |
| Hydraulic Head | 95 m |
| Crest Length | 820 m |
| Reservoir Area | $2.04 \times 10^9$ $m^2$ |
| Gross Storage | $2.2 \times 10^8$ $m^3$ |
| Date Completed | November 1964 (filling started) |
| Foundation Rock | graywacke and argillite |

This investigation incorporates the results of studies of seismicity and faulting in the vicinity of Lake Benmore by personnel of the New Zealand Geological Survey in New Zealand. The studies for this report were selective and limited in scope; it was not intended that all faults in the area be identified and evaluated. For the purposes of this study, it was assumed that any Late Cenozoic faults within the hydrologic regime of the reservoir may be influenced by impoundment of the reservoir.

The scope of this study's work consisted of the following:

- gathering and reviewing published and unpublished data and maps;

- questioning scientists resident in, or familiar with, the study area;

- making aerial reconnaissance flights over the study area;

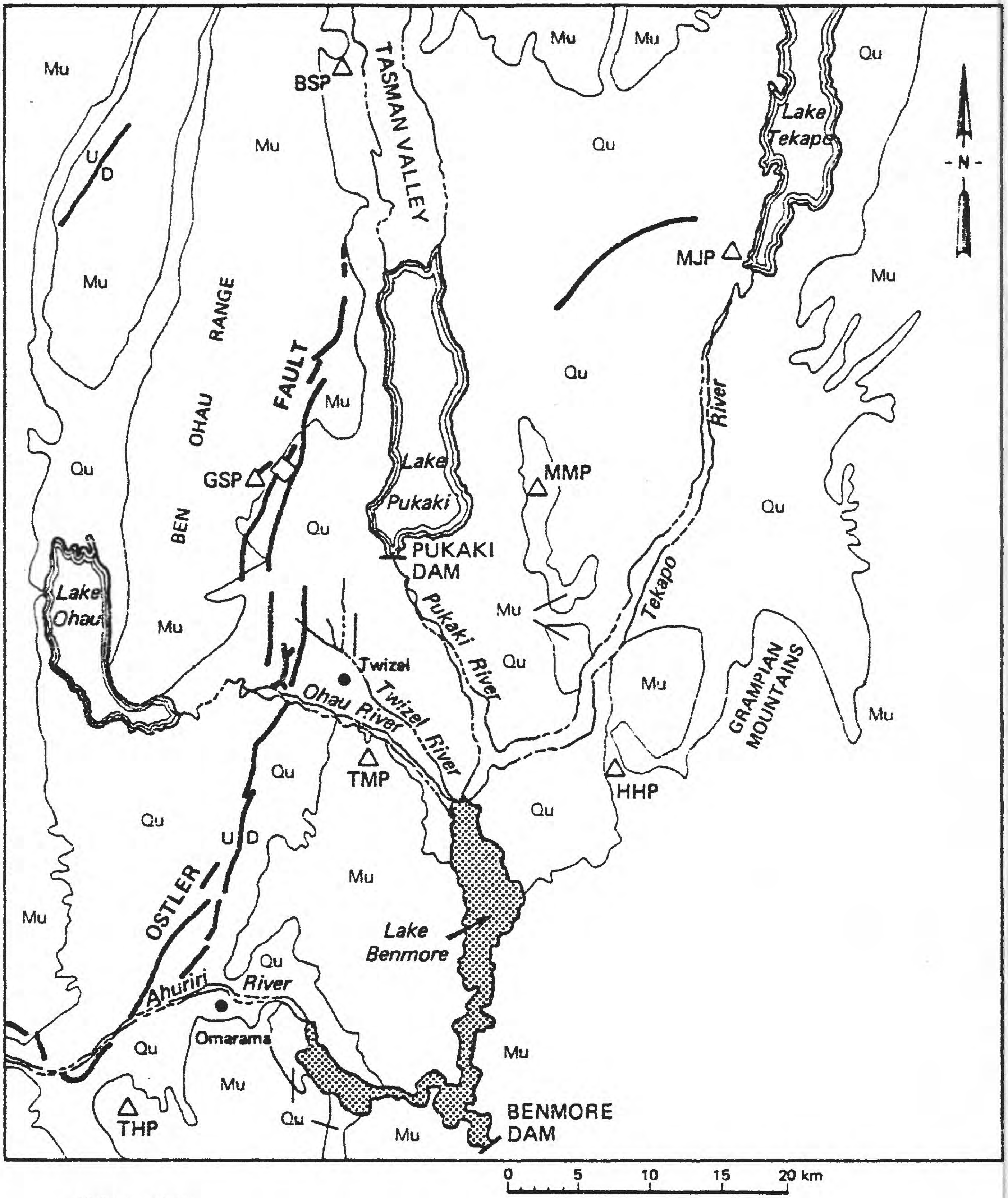
- performing ground reconnaissance at selected locations in the study area;
- examining LANDSAT imagery and aerial photographs of portions of the study area; and
- collecting and evaluating seismic data.

The initial part of the data gathering effort was performed in our offices in San Francisco, using Woodward-Clyde Consultants' library facilities and files. Additional data and maps were obtained from government agencies in Lower Hutt, Wellington, and Twizel, New Zealand. Selected references also were reviewed in the library of the New Zealand Geological Survey, and complete seismologic data were obtained from the Seismological Observatory in Wellington. A reservoir filling history was requested from the Ministry of Works and Development, and aerial photographs were purchased from the Department of Lands and Survey.

## REGIONAL GEOLOGIC SETTING

Benmore Dam and Reservoir area is a complexly faulted basin and has a range topography in which regional uplift is believed to have continued into the Pleistocene period (Shaw and Stevens, 1966). However, much of the faulting in the region probably occurred during Tertiary time (McKellar and others, 1967).

The only recognized major historically active fault in the region is the Alpine fault, which is located 32 km northwest of Benmore Dam (Figure 4-32). However, evidence of Holocene activity along segments of other faults of potentially significant extent has been reported (Gair, 1967). The Ostler fault zone (Figure 4-35), which is described in detail later in this report, is an example.



**EXPLANATION:**

Geologic contact

U/D Active fault trace; relative movement indicated

△ Microseismic station

◇ Epicenter of December 1978 M 4.6 earthquake

Qu Undifferentiated Quaternary deposits, principally alluvium, till, and glacial outwash

Mu Undifferentiated Mesozoic bedrock, principally graywacke and argillite

Source: Gair (1967), Mutch (1963), and MacFarlane (1979)

REPORTED ACTIVE FAULT TRACES
VICINITY OF LAKE BENMORE
South Island, New Zealand

Project No. 14087A

Woodward-Clyde Consultants

Figure 4–35

The available geologic maps (Mutch, 1963; Gair, 1967) indicate that Benmore Dam and much of Lake Benmore are located on graywacke and argillite of Silurian age (Figure 4-35). A relatively minor portion of the reservoir is mapped as being located on similar materials of Permian age. The northern end of the reservoir is mapped as being located on Pleistocene alluvium and glacial till. The Pleistocene deposits are believed to reach a thickness in excess of 1518 m upstream from the reservoir (Mansergh and Read, 1973). A total of seven Pleistocene units have been recognized in the project area. In general, these consist of glacial till, outwash gravels, interglacial deposits, and alluvium.

REGIONAL SEISMIC ACTIVITY

Lake Benmore is located in an area of relatively low seismicity. During the pre-impoundment period (1955 to 1964), only 7 earthquakes of magnitude 4 or greater were reported to have been located within 80 km of Benmore Dam (Adams, 1974). During the post-impoundment period (1965-1972), a total of 29 earthquakes occurred within 80 km of the dam. Two of these events had a magnitude of 5, whereas the highest magnitude recorded between 1955 and 1964 was 4.4.

Earthquakes within radii of 40 and 60 km also show a statistical difference between pre-impoundment and post-impoundment seismicity: the number of earthquakes having magnitudes equal to or greater than 4 has increased by factors of 3.1 and 6.5 since impoundment of Lake Benmore. The factor of 3.1 applies to earthquakes within 60 km of the dam, and the factor of 6.5 relates to earthquakes within 40 km of the dam. In considering distance and azimuth together, Adams (1974) found that 50 percent of the earthquakes examined occurred in 10 percent of the area considered (upstream of the dam and within 40 km of it). However, reservoir impoundment in

December 1964 was not followed immediately by an increase in earthquake activity; the first magnitude 5 event did not occur until July 1966. The second magnitude 5 event occurred nearly 5 years later, in April 1971. Neither event could be correlated with changes in reservoir water level, as it has remained essentially constant since the intitial filling (Adams, 1974).

Woodward-Clyde Consultants reexamined the data base and incorporated additional data with that studied by Adams (1974). The locations of these events are shown on Figure 4-36.

The first magnitude 5 earthquake to occur following impoundment of Lake Benmore was plotted near the Otemata fault, about 17 km west of the dam (Adams, 1974). This fault is not mapped as a Quaternary feature (New Zealand Geological Survey, 1973). The second magnitude 5 earthquake to occur following impoundment was located approximately 14 km north of the dam, adjacent to the western shore of the reservoir and away from any known fault. This event suggests the possibility of the existence of a fault along the margin of the mountains where they join the Mackenzie Basin (Adams, 1974). A number of smaller events fall within a northeast-trending alignment, extending roughly along the mountain front (Adams, 1974). No surface evidence of the existence of a fault in this location has been reported.

Several post-impoundment earthquakes have been plotted within or adjacent to the Ostler fault zone. This zone, including its probably northern extension, is the only relatively well-documented Quaternary fault in the project area (Mansergh and Read, 1973). The largest and most recent earthquake that appears to be related to this fault zone was a magnitude 4.6 event that occurred on 17 December 1978. The epicenter was located on the northern extension of the Ostler fault zone, west of Lake Pukaki (Figure 4-36). The available data suggest a focal depth of approximately 4 km. Personnel of the New Zealand Geological Survey conducted a detailed examination of known fault traces in the epicentral area but found no evidence of surface fault rupture or other ground damage (Don Macfarlane, personal communication, December 1978). The pattern of first motions is reported to be consistent with sinistral strike-slip movement on a north-south fault. This interpretation is supported by the strong motion data, which showed most of the seismic energy to be in a north-south direction and of anomalously low amplitude in the epicentral area (Calhaem, 1978).

The seismic energy released in the December 1978 earthquake is reported to be more than 600 times the total energy released during the 3 1/2 year period immediately preceding that event (Calhaem, 1978). This earthquake occurred during rapid filling of Lake Pukaki. Lake Pukaki is a natural lake, the capacity of which has twice been increased by construction of dams designed to increase the power production capacity of the Upper and Middle Waitaki Power Scheme. The new Pukaki High Dam, which was completed in 1978, ultimately will create a reservoir with a maximum depth of 108 m and a storage capacity of more than $10 \times 10^9$ $m^3$. As a precaution against further seismic activity, the rate of filling of this reservoir was reduced by 50 percent following the 17 December 1978 earthquake (Calhaem, 1978).

During 1973, the New Zealand Institute of Geophysics recorded an 18-day survey of microearthquakes in the project area. This was done to establish in more detail the locations and mechanisms of earthquakes in the Benmore area and to ascertain the base level of seismicity prior to raising the level of Lake Pukaki. This portable network was capable of detecting

HISTORICAL MACROSEISMICITY
VICINITY OF LAKE BENMORE
South Island, New Zealand

Woodward-Clyde Consultants

Figure 4-38

and locating seismic events with magnitudes less than 0, as ompared to a higher limit of magnitude for the pre-existing fixed network. Two linear trends were identified from plotting located events. One extended in a northerly direction, from the vicinity of the town of Omarama to the Ben Ohau Range (Figure 4-35); this trend corresponds quite closely with the mapped position of the Ostler fault zone. The second trend extended in a northeasterly direction, from the northern arm of Lake Benmore along the edge of the Grampian Mountains (Figure 4-35). The most active areas along these two trends correspond closely to the postions of the two magnitude 5 earthqakes that had been recorded previously (Adams and others, 1974).

Although the main trend of epicenters appears to correspond closely with the Ostler fault zone, the calculated mechanisms indicate that the fault planes of individual earthquakes strike approximately 45 degrees from this alignment. This strike is consistent with that of the trend noted along the base of the Grampian Mountains. Both the computer microearthquake mechanisms and the geologically observed faulting are consistent with east-west regional compression (Adams and others, 1974).

FAULT INVESTIGATION

A small-scale map of active faults in New Zealand (Lensen, 1965) indicates the presence of a number of relatively minor active faults in the region surrounding Lake Benmore. The most extensive of these, and the one closest to the reservoir, is the Ostler fault zone (Figure 4-35). It is located approximately 10 km west of the western arm of Lake Benmore and approximately 18 km west of the center of the main body of the reservoir. It extends for at least 56 km, from the Ahuriri River on the south to the headwaters of the Twizel

River on the north (Gair, 1967). From there, the mapped relationships suggest that the fault may join a less recent fault system that extends northward into the Southern Alps, where it dies out in a fold. The axis of this fold is located subparallel to, and approximately 21 km southeast of, the Alpine fault, which is the most significant tectonic feature in New Zealand. The northern extension of the Ostler fault is approximately 40 km long and has been mapped as being active during Pleistocene, but not Holocene, time (New Zealand Geological Survey, 1973).

The Ostler fault zone, due to its proximity to a power plant site, has been studied in some detail by the New Zealand Geological Survey. These studies have included exploratory trenching and profiling. As described by Mansergh and Read (1973), the Ostler fault zone is made up of a series of individual traces within a band that locally may be as much as 5500 m wide (Figure 4-37). The most prominent of these traces in the study area are, from west to east, the Haybarn fault, the "Y" fault, and the Ruataniwha fault (Figures 4-38 and 4-39). Mansergh and Read (1973) state that the individual fault blocks within the zone generally are downthrown to the east and suggest that the locus of movement has migrated to the east with time. Tilted surfaces and folds are present within the zone.

The New Zealand Geological Survey (Mansergh and Read, 1973) has recognized two and possibly three areas where displacement of 1.8 to 2.7 m in alluvium occurred along the Ostler fault zone. Moreover, a total maximum displacement of 20 m was measured in 14,000-year-old glacial deposits, and 21 m in 16,000-year-old glacial deposits. On this basis, the average rate of fault movement has been estimated to be 14 m per thousand years. However, based upon maximum and minimum recognized individual episodes of offset of 6.1 to 6.7 m and

View is to the south, along the Ostler fault zone. Arrows indicate variations in scarp height in Quaternary units of different ages.

| OSTLER FAULT ZONE<br>VICINITY OF LAKE BENMORE<br>South Island, New Zealand | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4–37<br>Page 202 |

View is to the north, along the Haybarn trace of the Ostler fault zone. The left-lateral drainage offset can be seen near excavation scar.

| HAYBARN FAULT<br>VICINITY OF LAKE BENMORE<br>South Island, New Zealand | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4–38<br> |

View is to the north, along the Haybarn trace of the Ostler fault zone. The degraded fault scrap is visible. Left-lateral offset of small drainage crosses slope adjacent to geologist (in center of photograph).

| HAYBARN FAULT<br>VICINITY OF LAKE BENMORE<br>South Island, New Zealand | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4–39<br>Page 204 |

1.8 m, respectively, the recurrence interval of episodes of surface fault rupture has been estimated as 2800 years (Mansergh and Read, 1973).

The studies performed by the New Zealand Geological Survey indicate that the Ostler fault zone is the result of thrusting, with the west side moving up. Lake Benmore is located on the lower plate of the thrust, approximately 15 km to the east of the zone. An alignment of earthquake epicenters, all recorded since the filling of the reservoir in 1964, have been mapped within or immediately west of the zone. This seismicity has been described in detail by Adams (1973) and has been summarized previously in this report.

The Ostler fault zone was examined on the ground, from the air, and on aerial photographs. The three fault traces mapped in the Twizel area by the New Zealand Geological Survey (Mansergh and Read, 1973) are prominently visible in the aerial photographs. On these photographs and from the air, the Ostler fault zone is identifiable principally on the basis of aligned scarps. Some of the scarps are substantially higher than others and may represent erosional remnants. The ground surfaces on the western side of both the high scarps and the low scarps have, in general, a gentle westward tilt. This westward tilt also was observed in bedding planes exposed in road cuts and stream banks. Landslides were noted on a number of the higher scarps; however, no landslides were observed at locations away from the fault zone.

Some of the scarps, particularly the lower ones, are quite irregular and tend to follow the trace inferred by the New Zealand Geological Survey (Mansergh and Read, 1973). However, in gross aspect, the zone is quite linear. This is particularly true west of Lake Pukaki where the probable northern extension of the Ostler fault zone appears essentially as a straight line marking a break in slope along a precipitous mountain front. This pronounced linear trend, particularly when considered with the reported alignment of earthquake epicenters along the surface trace of the Ostler fault zone, strongly suggests that the major portion of the fault plane is nearly vertical, although it may "roll over" somewhat where it passes through deep alluvial and glacial deposits.

For the present study, the surface reconnaissance of the Haybarn trace of the Ostler fault zone found pronounced evidence of left-lateal ofset of small drainages. The amount of left-lateral offset appears to be substantially greater than the vertical displacement. This evidence of a strong left-lateral strike-slip offset supports the previously described evidence pointing to the existence of a nearly vertical fault plane. It also supports the focal mechanism interpretation for the December 1978 earthquake. The strongest geomorphic expression suggestive of recurrent offset was seen on the Ruataniwha fault trace, immediately north of the Ohau River. At this location, two fault traces appear to be closely intertwined, producing a scarp-like feature. The results of the present study and of evaluation of the mechanism of the December 1978 earthquake indicate that the Ostler fault zone, which previously had been considered to be a westward-dipping thrust fault, is a nearly vertical, left-lateral strike-slip fault along its eastern portion.

CONCLUSIONS

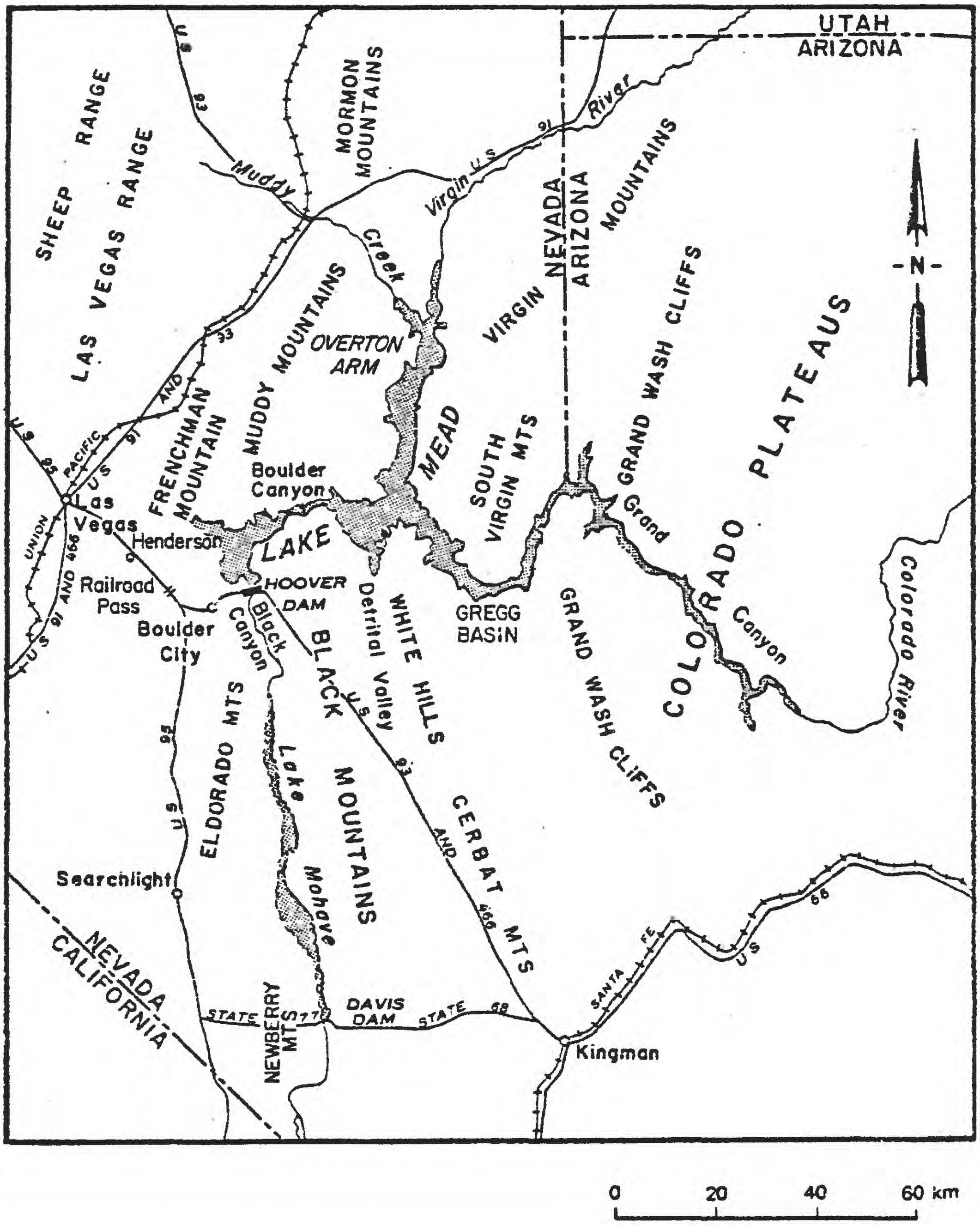
The available data demonstrate a pronounced and significant increase in local seismicity following impoundment of Lake Benmore. Some of the earthquakes that have occurred since impoundment of Lake Benmore and that have been suspected of being induced by it have been located along or closely adjacent to the Ostler fault zone. (The center of Lake Pukaki is located about 8 km to the east of the Ostler fault zone.) The Ostler fault zone contains faults that have had surface displacement during the current tectonic regime, as expressed by scarps in Pleistocene deposits and on Holocene surfaces. The most recent earthquake on this fault, which occurred on 17 December 1978, may have been triggered by rapid filling of Lake Pukaki.

## 4.6 HOOVER DAM AND LAKE MEAD, UNITED STATES

### INTRODUCTION

Lake Mead, impounded by construction of Hoover Dam across the Colorado River at the Arizona-Nevada border in Black Canyon (Figure 4-40), is one of several large, deep reservoirs that have been responsible for inducing or triggering an increased level of local seismicity. This report describes the results of preliminary studies undertaken to evaluate the possibility that the reservoir is underlain or closely bordered by one or more active faults. For the purposes of this study, an active fault is one on which displacement has occurred during that area's present stress regime; for the Lake Mead area, this would be Late Cenozoic time.

In part, these studies are an extension of earlier work by others who had correlated some of the recorded seismic events with mapped geologic structures. However, the present studies were selective and limited in scope; it was not intended that all faults in the area be evaluated. For the present study, a brief review of pertinent available data was made. The locations of selected faults and seismically active areas described in the literature were marked on topographic maps to facilitate the field studies. Selected areas were examined for regional trends on aerial photographs (scale 1:80,000) provided by the U.S. Geological Survey. Areas and linear trends of potential interest and significance were then viewed during aerial reconnaissance flights. Selected areas accessible by foot or four-wheel drive vehicle were examined during the ground reconnaissance. Extensive 35 mm photo coverage of the study areas was taken for reference during data evaluation.



Source: After Longwell (1963)

LOCATION MAP
HOOVER DAM AND LAKE MEAD
Arizona and Nevada, United States

Project No. 14087A
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Figure 4–40

REGIONAL GEOLOGIC SETTING

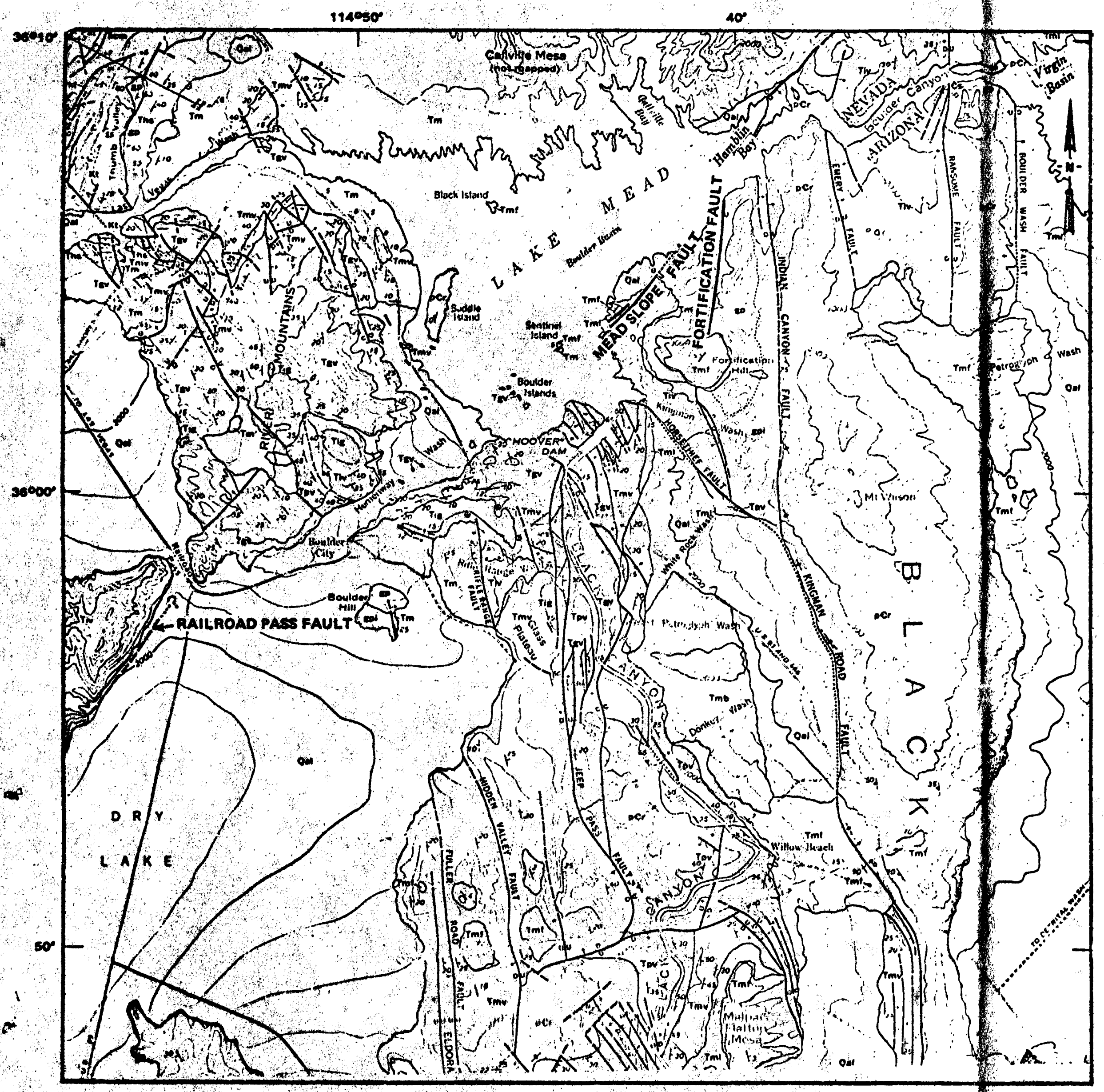
Hoover Dam impounds the Colorado River in northwestern Arizona and southeastern Nevada forming Lake Mead; the maximum depth of the reservoir is approximately 166 m. The dam and reservoir are located in the Basin and Range physiographic province, which is characterized by regional extension, resultant normal faulting, and horst and graben structures (Figure 4-41). The dam itself is underlain by Tertiary volcanic deposits of basalt and andesite. The reservoir also is underlain by Tertiary volcanic deposits and by Tertiary conglomerate, sandstone, clay, salt, and gypsum deposits, Precambrian metamorphic units, and Precambrian granite (Longwell, 1936; Rogers and Lee, 1976).

Faulting is prevalant in the vicinity of the dam site and in the reservoir area. The faults are late Tertiary in age and are primarily strike-slip faults that trend northeast and normal faults that trend north (Anderson and Laney, 1975). The two major strike-slip faults, the Las Vegas shear and the Hamblin Bay fault, are estimated by Rogers and Lee (1976) to be approximately 64 to 80 km long. Cumulative displacements on the normal faults measure approximately 1800 m, according to the same authors. A large number of faults of lesser extent have been mapped (Figure 4-41).

REGIONAL SEISMIC ACTIVITY

Prior to reservoir impoundment in 1936, no historical earthquakes had been reported near the reservoir, and the area was considered to be one of extremely low seismicity. Seismic activity, which commenced subsequent to reservoir impoundment, was clustered within 25 km of the reservoir. During an 8-year monitoring period beginning in 1937, epicenters were centered primarily along existing faults at focal depths of less than

80-1092



EXPLANATION

*Pleistocene and Recent* — QUATERNARY

Qal

Alluvium and lake deposits

*Gravel, sand, and silt (Recent); lake deposits of Chemehuevi formation (Pleistocene); early deposits of Colorado River; and cemented slope gravels, locally cut by dikes and overlain by basaltic lavas (Pleistocene?)*

*Pliocene(?)* — TERTIARY

Tm | Tmf | Tmb | Tml

Muddy Creek formation

*Conglomerate, sandstone, silt, clay gypsum, and basalt flows; local breccia of landslide origin. South and east of Lake Mead.*

*Tmf, Fortification basalt member, at top, underlain by lower part of formation, or by older rocks beyond limits of deposition of lower part of Muddy Creek*

*Tml, lower part of Muddy Creek formation*

*Tmb, breccia of landslide origin, locally present within lower part of Muddy Creek*

*Eocene(?) to Miocene(?)*

Tiv

Volcanic and intrusive rocks

*In part hydrothermally altered, ranging in age from Patsy Mine to Mount Davis. Sedimentary rocks north of Boulder Canyon are included*

Tig

Intrusive rocks

*Intrusive bodies cutting Mount Davis or older volcanic rocks; locally including masses of invaded rocks*

Tmv

Mount Davis volcanics

*Basalt and dark andesite predominant; widespread tuff and glass; abundant sedimentary breccia*

Tgv

Golden Door volcanics

*Latite to rhyolite; abundant explosion breccia, tuff, and rhyolite glass*

Tpv

Patsy Mine volcanics

*Brown andesite, with much basalt in upper part; one sheet of rhyolite glass containing spherulites*

*Eocene(?)* — TERTIARY(?)

Ths

Horse Spring formation

*Fresh-water limestone, siltstone, sedimentary breccia, volcanic tuff, and basaltic lava*

CRETACEOUS(?) AND YOUNGER

gp | gpi

Intrusive rocks

*Granitic rocks and porphyry, visibly in contact with prevolcanic rocks or isolated by alluvium, gp. No known intrusive contacts with Tertiary volcanic rocks. May be in part equivalent to Tig unit. Similar rocks with interspersed masses of invaded Precambrian complex, gpi; boundaries vague*

CRETACEOUS(?)

Kt

Thumb formation

*Reddish-brown sandstone and siltstone, fresh-water limestone, gypsum, conglomerate, coarse breccia, and basaltic lava*

TRIASSIC

ℏcm

Chinle and Moenkopi formations

*Shale, sandstone, conglomerate, limestone, and gypsum*

PERMIAN

Pkt

Kaibab and Toroweap formations

*Includes Permian red beds locally*

CAMBRIAN

Cs

Sedimentary rocks

*Limestone and shale, in part thermally altered*

PRECAMBRIAN

pCr

Metamorphic and igneous rocks

*Complex of gneiss, schist, and granitic rocks. Many included igneous bodies of Cretaceous or later age, not mapped separately*

Contact

*Dashed where approximately located, dotted where concealed*

U
D

Fault, showing dip

*Dashed where approximately located, dotted where concealed. U, upthrown side; D, downthrown side*

Anticline

*Showing position and plunge of crestline*

25

Strike and dip of sedimentary and volcanic rocks

90

Strike of near-vertical beds

Horizontal beds

10

Strike and dip of schistosity

Strike of vertical schistosity

Mine

Source: Longwell (1963)

0 2 4 6 8 km

GEOLOGY AND REPORTED FAULTS
VICINITY OF HOOVER DAM
Arizona and Nevada, United States

Project No. 14087A
**Woodward-Clyde Consultants**

Figure 4—41

Page 211

9 km. The largest earthquakes were assigned Richter magnitudes of 5 and occurred in 1939, 1942, 1948, 1952, and 1958 (Rogers and Lee, 1976). Studies of these earthquakes (occurring between initial maximum impoundment in 1938 until about 1948 or 1949) suggest that a correlation exists between seasonal variations in reservoir level and variations in the frequency of seismic activity (Carder, 1970). However, subsequent seismic activity from 1949 to 1976 shows no correlation with a 20 percent increase in reservoir load. Analysis of the data from monitoring of the lake area during 1972 and 1973 showed seismic activity to be no different than that of the surrounding region.

Carder (1968, 1970) suggests that the post-impoundment seismicity may be the result of stresses generated by the weight of Lake Mead triggering renewed activity along pre-existing normal faults. The bases for this hypothesis are that the basin in which Lake Mead is impounded settled 18 to 20 cm (Carder and Small, 1948; Lara and Sanders, 1970) and that the time between initial maximum impoundment (1938) and the largest reported events (the first occurring in 1939) was relatively short. Information on surface rupture along these faults or the duration and nature of ground motion associated with the post-impoundment seismicity was not presented in the reports reviewed during this study.

## FAULT INVESTIGATION

A relatively large number of faults within the Lake Mead reservoir area and surrounding region are described in the literature. It was not possible within the scope of this study either to document all the available data on each or to examine each one in any significant detail. Therefore, it was necessary to be selective and to choose only a few faults for study. Because the emphasis of this preliminary study was on recognition of geologically recent faulting, the greatest attention was directed to features that either border alluvium or have been reported to offset alluvium. Twelve geographic areas were studied: three of these areas yielded information most significant to this study, and the geologic reconnaissance findings from these areas are discussed below (Figure 4-41).

### Railroad Flat - Black Mountain Area

A fault, largely concealed by alluvium, is possibly located southwest of Railroad Pass (Longwell, 1963). The findings from another study in the area (Woodward-McNeil & Associates, 1974) strongly suggest geologically recent surface rupture on a fault that may correspond with the one referred to by Longwell (1963). Rogers and Lee (1976) indicate the presence of a fault in this same general vicinity, but do not show any corresponding lineation of epicenters. Nevertheless, Carder (1945) indicates that some seismic activity has occurred in this area.

The geologic features noted during the current study include two adjacent lines of scarps with a northeast trend, parallel to the base of Black Mountain, which is located about 11 km southwest of Boulder City, Nevada. These lines of scarp, which presumably represent a fault zone, are intermittent and are traceable for a distance of about 3 km across colluvial fans, a boulder debris flow, and a pediment surface. One scarp is most distinctive where it crosses the debris flow. The northwest side of this scarp is 3.5 to 4.5 m higher than the east side and can best be seen during the late afternoon, when the sun angle produces a shadow on the east side of the scarp, enhancing its expression.

The sense of displacement on the fault appears to be mainly normal. No obvious indication of a strike-slip component was noted, although the channel of one wash may be shifted to the right across the fault. A steep-sided topographic slope about 3.5 to 4.5 m high is evident near the crest of the debris flow east of a gorge in Black Mountain. The fan surface consists principally of very large boulders, as large as 1.8 m in diameter. The scarp continues beyond the main portion of the youngest debris flow. Within the main channel of the fan complex, the older debris material is exposed and is overlain by younger, fresher granitic rock slide and debris flow material. The older material is coated with desert varnish and is also granitic in composition.

The line of scarp feature is traceable to the north as far as Highway 93 and projects into a notch in a foothill ridge of the River Mountains just north of Highway 93. Evidence for the location of the line of scarps becomes less clear both to the north and south of the debris flow. Traces of the scarp are clearly seen across two drainages just to the north of the debris flow and are marked by a vertical displacements of a pediment surface between the drainages. The scarp is also marked by a line of vegetation that is aligned with the more prominent scarp that crosses the apex of the debris flow. Another, less evident subparallel feature exists to the southeast and is marked by a vegetational line. These geologic features are judged to represent surface expressions of faulting during the present tectonic regime and may represent late Holocene displacement.

During aerial reconnaissance, no definitive evidence was observed to demonstrate that this geologic structure exists as far northeast as Lake Mead; however, there is the possibility that it still exists, based on several topographic saddles and other subtle features along the projection of the fault.

## Mead Slope Fault

The Mead Slope fault has been described as one of a group of four faults in the vicinity of Fortification Hill (Longwell, 1963). According to Longwell, this is a reverse fault that may have originated after the older river gravels (presumably of Pleistocene age) were deposited. The Mead Slope fault is shown to cut the Muddy Creek Formation of Pliocene(?) age, and its northwesterly side is indicated to be relatively downthrown (Longwell, 1963, Plate 1). Moreover, a number of earthquake epicenters have been found to be closely associated with faults in the vicinity of Fortification Hill (Mead and Carder, 1941). The Mead Slope fault is marked by strong linear trends of scarps, drainage alignments, and vegetational contrasts. Two parallel lineaments were noted from the aerial photographs, aerial reconnaissance, and ground reconnaissance. The scarps are oriented in a northwest direction and are traceable across a gently northwest-sloping, dissected surface on the south shore of Lake Mead, just northwest of Fortification Hill. The fault cuts northward-dipping Tertiary-age fanglomerates, caliche beds, 2.4 to 3 m thick, that are associated with the upper pediment surface, low terrace surfaces, and debris flows in present-day channels.

The fault is exposed in the cliff above Castle Cove and is traceable almost continuously for a distance of 3 km across the northwest-sloping suface. Scarps are exposed at the north end of the northeast projection of the fault across Lake Mead towards Hamblin Bay. The northeastern end of the scarp is down on the northwest side. The scarp appears to be about 3 m in height. The southwestern end of the trace is represented along its strike by an eroded trough that contains a relatively lower density of basalt cobbles and, in some places, exposures of an underlying caliche unit. Stream beds appear to have been diverted or displaced along this trough.

The younger material is on the northwest side of the fault; however, the sloping surface on the younger northwestern side of the fault where it crosses the second nose of the pediment surface to the north of Castle Cove appears to be even with or slightly higher than the older material to the southeast. A second, less-prominent subparallel feature, marked by a vegetational line, is located to the northwest of the main trace.

### Lime Ridge Area

Longwell (1928) mapped a normal fault along the base of the hills east of the lower Virgin River Valley, which is now the Overton Arm of Lake Mead (Figure 4-40). This north-south trending feature, as mapped, is offset by three northeast-striking normal faults, and it forms the boundary between Quaternary alluvium and the Callville limestone of Pennsylvanian age. The youngest formation offset by this fault, as mapped, is the Overton fanglomerate of Miocene age.

A geologic feature reflecting young faulting is located between the north-south trending Overton arm of Lake Mead and Lime Ridge. This feature shows as two separate subparallel lineament trends that are recognizable on 1:80,000 scale black and white photographs (Figure 4-42) and during aerial reconnaissance. The lineaments trend in a northeast direction and are 6 to 8 km in length. They are marked by topographic scarps and indicate the boundaries of a graben structure across a gently sloping, dissected erosional surface of Tertiary deposits. The easternmost scarps are west-facing and are higher than the westernmost, which are east-facing. From the air, the western-facing scarps appear to be about 3 to 6 m high, and the eastern-facing scarps appear to be about 1.5 to 3 m high. No clear evidence for strike slip movement was observed.

NOTE:
Lineaments indicated by arrows.

| LIME RIDGE AREA<br>HOOVER DAM AND LAKE MEAD<br>Arizona and Nevada, United States | |
|---|---|
| Project No. 14087A<br>**Woodward-Clyde Consultants** | Figure 4–42 |
| | Page 217 |

The graben structure is not evidenced south of the westward-flowing Quail Springs Wash and not as clearly marked north of the westward-flowing Lime Wash. The easternmost scarp appears well marked in alluvium and terrace material by a scarp crossing the mouth of Lime Canyon. It can be traced for several miles to the north as a west-facing scarp. Less well defined westward-trending strike slip fault planes may offset or terminate the north-trending normal faults.

## CONCLUSIONS

Geologic and topographic evidence strongly suggestive of Late Cenozoic fault activity was observed at three locations in or near the Lake Mead reservoir area. These are: the Railroad Flat-Black Mountain area, the Fortification Hill area (Mead Slope fault), and the Lime Ridge area. Of these three areas, only the Fortification Hill area contains faults that underlie the reservoir. However, the other areas are within a few kilometers of the reservoir and can reasonably be considered to be within its influence.

## 5.0 SUMMARY AND CONCLUSIONS

The number of impounded reservoirs having maximum water levels greater than 92 m (deep) and/or maximum water volume greater than $10^{10}$ $m^3$ (very large) has increased from approximately 60 in 1960 to more than 230 in 1979, and is projected to increase to approximately 275 by 1985. Projections from the past 20 years suggest that at least 10 more cases of reservoir induced seismicity is likely to occur prior to 1985 at deep and/or very large reservoirs alone. In the past, some RIS occurred in areas of low historical seismicity where the design of dams had not fully anticipated an earthquake as large as that which occurred, and, therefore, the potential for damaging reservoir induced earthquakes is also increasing.

The impoundment of many reservoirs has significantly influenced the temporal and spatial patterns of earthquake occurrence in the vicinity of the reservoir. For some of the more than 75 reported cases of reservoir induced seismicity, the seismicity is clearly related to reservoir impoundment and water fluctuations, whereas for others it is not. For more accurate evaluations of the theoretical mechanisms of reservoir induced seismicity of the methods to mitigate potential effects, or of the prediction of occurrence of reservoir induced seismicity, those cases of actual reservoir induced seismicity must be distinguished from those cases where reported seismicity most likely was not related to the reservoir impoundment. In this study, the influence of the reservoir on local macro- and micro-seismicity has been evaluated for each reported case of reservoir induced seismicity. Where post-impoundment seismicity had a demonstrable spatial and/or temporal relationship to the reservoir, the case for reservoir induced seismicity is classified as accepted. Where it was clearly established as being unrelated to the reservoir, the case is classified as not reservoir induced seismicity. Where the relationship is unclear because of insufficient data, the case is classified as questionable reservoir induced seismicity. Of the 75 or so reported cases of reservoir induced seismicity, 64 were considered in our classification; 45 were assessed to have accepted reservoir induced seismicity, 7 were assessed not to have reservoir induced seismicity, and 12 were assessed as questionable. Of these 45 cases of accepted RIS, 16 were recognized as accepted reservoir induced seismicity at macro- and micro-seismicity levels, 14 were recognized at macro levels only, and 15 were recognized at micro levels only.

A population of 234 deep and/or very large reservoirs having maximum depths greater than 92 m and/or maximum volume greater than $10^{10}$ $m^3$ was selected to investigate the probability of occurrence of reservoir induced seismicity. There are 29 accepted cases of reservoir induced seismicity among these reservoirs and the prior probability of RIS is 0.12. Data on the depth, volume, regional stress regime, and predominant rock type of reservoir geology were collected for each reservoir. Data on active faulting in the vicinity of the reservoirs were obtained in some cases, but data were insufficient for the statistical analysis. A multivariate probabilistic model was constructed for the conditional probability of reservoir induced seismicity at a reservoir characterized by its depth, volume, stress, rock type, and faulting. The analysis suggested a higher occurrence of reservoir induced seismicity with increasing depth, with increasing volume, among reservoirs with predominantly sedimentary rock underlying the reservoir, and among reservoirs in a strike-slip (shear) stress regime. Of these four variables, depth and volume were most strongly correlated with reservoir induced seismicity. A sensitivity analysis indicated that these conditional probabilities are very sensitive to changes in data classification among the reservoir induced seismicity cases because of the relatively small size of the reservoir induced seismicity data set. This is particularly true for the regional stress regime and geology data; therefore no strong conclusions about the relationship between reservoir induced seismicity and the regional stress regime or geology were drawn.

A review of theoretical models of reservoir induced seismicity, including fluid-filled models, show that models have been used to successfully predict ground deflection and can explain seismicity occurrence during initial filling and observed delays in the occurrence of seismicity associated with small changes in water level. The fluid-filled models allow for much larger stresses to be generated at depth either by pressure increase or by zones of low permeability. These models also explain the occurrence of seismicity away from the center of the reservoir.

Models of the stresses created by the filling of reservoirs suggest that reservoir filling does not provide sufficient stress to initiate new fracturing and must trigger the release of stress along pre-stressed faults. This implies that displacements resulting from reservoir induced earthquakes on such pre-stressed, tectonically active faults must have occurred as a result of the present or active tectonic stress regime. The existence of active faults was investigated by field reconnaissance at 6 of the 11 reservoirs that had induced earthquakes of maximum magnitudes greater than or equal to 5. Of these 11 reservoirs, 9 have evidence indicating active faulting near the reservoir and two probably have active faults, although the evidence is not conclusive. The results of these field reconnaissance studies suggest that active faults are present within the influence of reservoirs that have triggered earthquakes with magnitudes greater than or equal to 5 and that these reservoirs have not triggered surface displacement along inactive faults.

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# STUDY OF
# RESERVOIR INDUCED SEISMICITY

## APPENDIX A

## DATA FOR RESERVOIRS STUDIED

FINAL TECHNICAL REPORT

August 1979

By

Duane R. Packer, Lloyd S. Cluff,
Peter L. Knuepfer and Robert J. Withers

Sponsored By The
U.S. Geological Survey
Contract No. 14-08-0001-16809

WOODWARD-CLYDE CONSULTANTS
Consulting Engineers, Geologists, and Environmental Scientists
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The views and discussions in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the United States Government.

# TITLE PAGE

1. CONTRACT NO.: 14-08-0001-16809
2. NAME OF CONTRACTOR: Woodward-Clyde Consultants
3. CO-PRINCIPAL INVESTIGATORS: Lloyd S. Cluff and Duane R. Packer
4. GOVERNMENT TECHNICAL OFFICER: Dr. Jack F. Evernden
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8. AMOUNT OF CONTRACT: $199,433.00
9. DATE REPORT SUBMITTED: August 1979

# APPENDIX A

# DATA FOR RESERVOIRS STUDIED

## Table of Contents

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# APPENDIX A
# DATA FOR RESERVOIRS STUDIED

## A.1 EXPLANATION

Data have been gathered on all deep (maximum water depth of 92 m or greater) and/or very large (maximum water volume of $10^{10}$ $m^3$ or greater) reservoirs completed as of the end of 1975 and for all cases of reservoir induced seismicity (RIS) reported as of the end of 1978. These data include reservoir size, water impoundment and fluctuation history, regional and local geology, stress conditions and faulting, hydrology, and seismicity. A full list of the data categories identified for compilation is included in Table A-1. Data for some of these categories were more readily available, and particular emphasis was placed on collecting complete data on regional stress, local geology, depth, and volume that could be used in statistical analysis. Data collection techniques are discussed in Section 2.2 of this report.

The listings of data for each reservoir are arranged in alphabetical order, according to dam name. For reservoirs with more than one major dam, the data are listed under the name of the largest dam; information on other major dams associated with a reservoir is provided within the data listing under the largest dam.

Certain data entries contain parentheses; these indicate which case or numeric entry was selected for comparison with other reservoir data. An example is "earth () and rock fill dam with concrete gravity spillway"; here, "earth" is selected for comparison with other reservoirs.

Reference sources are numbered for each dam listing. These reference numbers are keyed to citations in the List of References, Section 6 of this report. During this study, papers referring to engineering, geologic, and seismologic features of reservoirs or regions have been listed under the general heading "geologic references."

# TABLE A-1
# LIST AND EXPLANATIONS OF DATA PARAMETERS

| Data Items | Type of Data* | Comments |
|---|---|---|
| RESERVOIR IDENTIFICATION AND LOCATION | | |
| Dam Name | a | |
| Reservoir name | a | |
| Country | a | |
| River | a | |
| Location of center of reservoir | Lat/Long (1/2 way along length of reservoir from dam) | decimal or degrees: minutes: seconds |
| Location of dam | Lat/Long | |
| Province or region | a | |
| Dam type | case | gravity<br>rock<br>arch<br>earth<br>multi-arch |
| Date dam completed | date | floating point number or day--month-year- |

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*a = primary data, text
N = primary data, numerical value
case = primary data, specific term

Table A-1 (continued)

| Data Items | Type of Data | Comments |
|---|---|---|
| HISTORY OF IMPOUNDMENT | | |
| Notes on history of impoundment | a | include degree of confidence |
| Date of start of filling | date | |
| Rate of initial filling | N | meters/month; month is 1/12 of year |
| Years required from initial to maximum fill | N | decimal years |
| Maximum rate of filling | N | meters/month |
| Maximum rate of drawdown | N | meters/month |
| Expected fluctuations based on primary use | | flood control, irrigation, hydropower, public water supply; can also put in rate or volume as long form information |
| ORIENTATION AND SIZE | | |
| Notes | a | |
| Orientation of reservoir | direction | |
| Structural height of dam | N | height (in meters) from lowest foundation |
| Length of dam | N | meters |
| Maximum depth of reservoir | N | meters |
| Reservoir depth (computed from dam height) | N | meters; see Section 2.2.1 for explanation of computation procedure |

Table A-1 (continued)

| Data Items | Type of Data | Comments |
|---|---|---|
| Maximum volume of reservoir | N | $\text{meters}^3 \text{x} 10^6$ |
| Surface area of reservoir | N | $\text{kilometers}^2$ |
| Longest dimension of reservoir | N | kilometers |
| GEOLOGY | | |
| Notes on regional geology | a | |
| Regional geology | case | coarse clastic<br>fine clastic<br>carbonate<br>metamorphic<br>batholithic<br>volcanic |
| Age of regional geology | a | Geologic epoch or numerical age |
| Tectonic province | a | |
| Regional stress regime | case | extensional<br>compressional<br>shear |
| Evidence for regional stress regime | case | measurements<br>focal mechanism<br>faulting sense<br>tectonics |
| Confidence in regional stress regime evaluation | case | high<br>medium<br>low |
| Notes on geology site | a | |
| Site geology | | coarse clastic<br>fine clastic<br>carbonate<br>metamorphic<br>batholithic<br>volcanic |

Table A-1 (continued)

| Data Items | Type of Data | Comments |
|---|---|---|
| Age of site geology | a | |
| Structural grain orientation | direction | |
| Degree of deformation | case | flatlying<br>shallow dipping<br>steeply dipping<br>vertical<br>overturned<br>strongly deformed |
| FAULTING | | |
| Faulting notes | a | |
| Predominant fault type | case | thrust<br>strike-slip<br>normal<br>right-slip<br>left-slip<br>reverse<br>oblique<br>normal right<br>normal left<br>reverse right<br>reverse left |
| Azimuth of predominant faulting | direction | |
| Dip of predominant faulting | direction | |
| Maximum length of faults | N | kilometers |
| Dominant side up | direction | |
| Predominant fracture orientation | direction | |
| Location of reservoir in relation to faults | case | upthrown block<br>downthrown block |

Table A-1 (continued)

| Data Items | Type of Data | Comments |
|---|---|---|
| Name of closest known fault | a | |
| Distance to closest known fault | N | kilometers |
| Age of most recent displacement on closest known fault | a | geologic age or date |
| Rate of slip on local faults | N | centimeters/year |
| Activity of local faults | case | Yes<br>No<br>Unknown |
| Seismicity associated with faults in local area | case | Yes<br>No<br>Questionable |
| HYDROLOGY | | |
| Notes on hydrology | a | |
| Permeability of rocks | case | low<br>medium<br>high<br>(numeric data can be added) |
| Type of permeability | case | fracture<br>intergranular<br>cavernous<br>impervious |
| Ground-water gradient | case | low<br>medium<br>high |
| Relief | case | low<br>moderate<br>high |

Table A-1 (continued)

| Data Items | Type of Data | Comments |
|---|---|---|
| SEISMICITY | | |
| Seismic province | a | name |
| | N | kilometers2, area |
| Seismic subprovince | a | name |
| | N | kilometers2, area |
| Radius of Reservoir Local Area | N | kilometers2 |
| Distance from dam to nearest earthquake before filling | N | kilometers |
| Distance from dam to nearest earthquake after filling | N | kilometers |
| Time to first earthquake after filling in Reservoir Local Area | N | decimal years |
| Date of first catalog entry | date | |
| Date of last catalog entry | date | |
| Maximum depth of earthquakes in province before reservoir impoundment | N | kilometers |

Table A-1 (continued)

| Data Items | Type of Data | Comments |
|---|---|---|
| Maximum depth of earthquakes in province after reservoir impoundment | N | kilometers |
| Minimum depth of earthquakes in province before reservoir impoundment | N | kilometers |
| Minimum depth of earthquakes in province after reservoir impoundment | N | kilometers |
| Maximum depth of earthquakes in Reservoir Local Area before reservoir impoundment | N | kilometers |
| Minimum depth of earthquakes in Reservoir Local Area before reservoir impoundment | N | kilometers |
| Date of first suspected RIS event | Date | |
| Magnitude of intensity of largest suspected RIS event | N | $M_L$ (Richter magnitude) |

Table A-1 (continued)

| Data Items | Type of Data | Comments |
|---|---|---|
| Date of largest suspected RIS event | Date | |
| Mean Event | N | $M_L$ (Richter magnitude) |
| Number of foreshocks to largest RIS event | N | |
| Character of foreshocks | N | year $^{-1}$ |
| Number of aftershocks to largest RIS event | N | |
| Character of aftershocks | N | year $^{-1}$ |
| Network history before reservoir impoundment | a | |
| Network history after reservoir impoundment | a | |
| Notes on seismicity before impoundment | a | |
| Notes on seismicity after impoundment | a | |

Table A-1 (continued)

| Data Items | Type of Data | Comments |
|---|---|---|
| NOTES | | |
| General notes | a | |
| RIS category | case | accepted<br>questionable<br>not-accepted |
| Type of RIS | case | macro<br>micro<br>macro and micro |
| Geology references | N | refers to numbers on List of References |
| Seismology references | N | |

# A.2

# COMPUTER LISTING OF RESERVOIRS (alphabetical)

Agua del Toro

DAM NAME : Agua del Toro
COUNTRY : Argentina
RIVER : Tunuyan
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 120. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 102.00 m
MAXIMUM VOLUME OF RESERVOIR : 432. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 107,108

Agua Vermelha

DAM NAME : Agua Vermelha
COUNTRY : Brazil
RIVER : Grande
LOCATION OF CENTER OF RESERVOIR : 19.92S,49.92W
LOCATION OF DAM : 19.90S,50.45W
PROVINCE OR REGION : Sao Paulo/Minas Gerais
DAM TYPE : Earth () buttress with concrete gravity spillways
DATE DAM COMPLETED : 1978
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 90. (m)
LENGTH OF DAM : 3990. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 85.50 m
MAXIMUM VOLUME OF RESERVOIR : 11000. (m3x10E6)
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 108,306

Akosombo Main

DAM NAME : Akosombo Main
RESERVOIR NAME : Lake Volta
COUNTRY : Ghana
RIVER : Volta
LOCATION OF CENTER OF RESERVOIR : 7.50N, 0.25E
LOCATION OF DAM : 6.27N, 0.05E
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1965
DATE OF START OF FILLING : May-1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N (), NW
STRUCTURAL HEIGHT OF DAM : 134. m
MAXIMUM DEPTH OF RESERVOIR : 109.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.00 m
MAXIMUM VOLUME OF RESERVOIR : 165000. m3x10E6
SURFACE AREA OF RESERVOIR : 8730.00 km2
LONGEST DIMENSION OF RESERVOIR : 400.0 km
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : late Paleozoic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Alluvial sand up to 38 m depth removed to reach bedrock
PREDOMINANT FAULT TYPE : Reverse
MAXIMUM LENGTH OF FAULTS : 65.00 (km) km or greater
NAME OF CLOSEST KNOWN FAULT : Akwapim fault
DISTANCE TO CLOSEST KNOWN FAULT : 20.0 (km) km or less
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary, possibly Holocene
ARE LOCAL FAULTS ACTIVE? : yes
DATE OF FIRST SUSPECTED RIS EVENT : Nov-1964
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : MM V
DATE OF LARGEST SUSPECTED RIS EVENT : Nov-1964
NOTES ON SEISMICITY BEFORE IMPOUNDMENT : Historical seismicity in Accra, 100 km from dam; no historical seismicity reported near reservior.
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Epicenter of November 1964 earthquake south of reservoir along extension of active Akwapin fault. Event occurred when reservoir was filled to 1/6 capacity. No seismographs in Ghana at time of earthquake, but event felt at dam. Increase in post-impoundment seismicity; good spatial correlation with reservoir, clear temporal correlation with initial impoundment.
GENERAL NOTES : ISC reports earthquake of body magnitude 5.3 very close to the dam on 11 March 1964 but none in November. This is probably the same event with a confusion on the date. No other information could be found on this earthquake. A February 1969 earthquake also referred to in the reference, was detected by NOAA, but not by ISC. On this basis, the local agency reporting on the earthquakes probably has reliable information of date. The magnitude contradiction has still to be resolved.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 51, 74, 106, 268, 343, 466

Alcantara

DAM NAME : Alcantara
RESERVOIR NAME : Embalse de Alcantara
COUNTRY : Spain
RIVER : Tajo (Tagus)
LOCATION OF CENTER OF RESERVOIR : 39.72N, 6.48W
LOCATION OF DAM : 39.73N, 6.88W
PROVINCE OR REGION : Caceres
DAM TYPE : Concrete buttress gravity
DATE DAM COMPLETED : 1969
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Reservoir main arm oriented E-W; other arms NE and SE
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 130. m
LENGTH OF DAM : 570. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.00 m
MAXIMUM VOLUME OF RESERVOIR : 3137. m3x10E6
SURFACE AREA OF RESERVOIR : 104.00 km2
LONGEST DIMENSION OF RESERVOIR : 91.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Cambrian sub-vertical slatish phyllites and schists with near-vertical foliation. Granite outcrop 1 km from dam
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Cambrian
DEGREE OF DEFORMATION : Steeply dipping
GEOLOGY REFERENCES : 88, 104a, 107

## Aldeadavila

DAM NAME : Aldeadavila
RESERVOIR NAME : Embalse de Aldeadavila
COUNTRY : Spain
RIVER : Duero
LOCATION OF CENTER OF RESERVOIR : 41.25N, 6.58W
LOCATION OF DAM : 41.21N, 6.70W
PROVINCE OR REGION : Salamanca
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 123 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 139. m
LENGTH OF DAM : 333. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 121.50 m
MAXIMUM VOLUME OF RESERVOIR : 115. m3x10E6
SURFACE AREA OF RESERVOIR : 4.12 km2
LONGEST DIMENSION OF RESERVOIR : 29.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Granite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 104A, 106

Almendra

DAM NAME : Almendra
RESERVOIR NAME : Tormes Reservoir
COUNTRY : Spain
RIVER : Tormes
LOCATION OF CENTER OF RESERVOIR : 41.21N,6.16W
LOCATION OF DAM : 41.27N,6.36W
PROVINCE OR REGION : Salamanca
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1970
DATE OF START OF FILLING : Apr-1971
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S55E
STRUCTURAL HEIGHT OF DAM : 202. m
LENGTH OF DAM : 567. m
MAXIMUM DEPTH OF RESERVOIR : 185.0 (m) m (calculated from drawing)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 185.00 m
MAXIMUM VOLUME OF RESERVOIR : 2649. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 32.5 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : Tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : Low
SITE GEOLOGY : Batholithic () (granite)
DATE OF FIRST SUSPECTED RIS EVENT : Jan-1972
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Clear spatial and temporal correlation between microseismicity and initial impoundment; good correlation after initial impoundment. No pre-impoundment microseismic information. No apparent charge of spatial association in macroseismicity.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 72A,107,161

Alpe Gera

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DAM NAME : Alpe Gera
RESERVOIR NAME : Lago di Alpe Gera
COUNTRY : Italy
RIVER : Cormor
LOCATION OF CENTER OF RESERVOIR : 46.31N,9.95E
PROVINCE OR REGION : Lombardia (Sondrio)
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : 100 m maximum fluctuations in water level,1965 to 1968; Hydropower
NOTES ON DAM : Dam is 138 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 178. m
LENGTH OF DAM : 520. m
MAXIMUM DEPTH OF RESERVOIR : 135.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 135.00 m
MAXIMUM VOLUME OF RESERVOIR : 65. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 2.2 (km) km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Serpentine, schist, metavolcanics
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,451
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Alto Anchicaya

DAM NAME : Alto Anchicaya
COUNTRY : Colombia
RIVER : Anchicaya
LOCATION OF CENTER OF RESERVOIR : 0.50S,77.01W
PROVINCE OR REGION : Valle de Cauca
DAM TYPE : Rock () fill, concrete-faced
DATE DAM COMPLETED : 1974
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 140. m
MAXIMUM DEPTH OF RESERVOIR : 126.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 126.00 m
MAXIMUM VOLUME OF RESERVOIR : 45. m3x10E6
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Folded schist intruded by large and small bodies of quartz-diorite and amphibolite in project area. Hornfels found in 500 m-wide zone around intrusives. Small faults and shear zones in project area
SITE GEOLOGY : Metamorphic
NOTES ON FAULTING : No major regional faults
GEOLOGY REFERENCES : 107,108,182

Ambuklao

DAM NAME : Ambuklao
COUNTRY : Philippines
RIVER : Agno
LOCATION OF CENTER OF RESERVOIR : 16.48N, 120.80E
LOCATION OF DAM : 16.47N, 120.75E
PROVINCE OR REGION : Benguet, Luzon
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1955
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam 124 m above ground
ORIENTATION OF RESERVOIR : N10E
STRUCTURAL HEIGHT OF DAM : 129. m
LENGTH OF DAM : 606. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 116.10 m
MAXIMUM VOLUME OF RESERVOIR : 327. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 12.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Diorite, meta-andesite, meta-sediments (metatuffs and metasediments). Faults in both abutments.
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106, 145

## Anderson Ranch

DAM NAME : Anderson Ranch
RESERVOIR NAME : Anderson Ranch
COUNTRY : USA
RIVER : South Fork Boise
LOCATION OF CENTER OF RESERVOIR : 44.41N,115.35W
LOCATION OF DAM : 44.39N,115.45W
PROVINCE OR REGION : Idaho
DAM TYPE : Earth
DATE DAM COMPLETED : 1950
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (), hydropower, flood control
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 139. m
LENGTH OF DAM : 411. m
MAXIMUM DEPTH OF RESERVOIR : 101.0 (m) (reported, USBR)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 101.00 m
MAXIMUM VOLUME OF RESERVOIR : 608. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 17.0 (km) km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 107

Angat

DAM NAME : Angat
COUNTRY : Philippines
RIVER : Angat
LOCATION OF CENTER OF RESERVOIR : 14.90N, 121.18E
LOCATION OF DAM : 14.88N, 121.15E
PROVINCE OR REGION : Bulacan, Luzon
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (), multi-purpose; hydropower is principal use
NOTES ON DAM : 125 m above ground; lake extends north and south from dam.
ORIENTATION OF RESERVOIR : N10E
STRUCTURAL HEIGHT OF DAM : 128. m
LENGTH OF DAM : 525. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 115.20 m
MAXIMUM VOLUME OF RESERVOIR : 920. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 35.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Pre-Tertiary metamorphosed lavas and sedimentary rocks intruded by andesite dikes.  Sedimentary strata bedding, N30E at dam, slight dip.  Shear zones recemented by quartz and other materials exposed in abutments
SITE GEOLOGY : Coarse clastic
GEOLOGY REFERENCES : 106, 145

Arimine

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DAM NAME : Arimine
COUNTRY : Japan
RIVER : Joganji
LOCATION OF CENTER OF RESERVOIR : 36.46N,137.41E
LOCATION OF DAM : 3648.00N,137.95E
PROVINCE OR REGION : Toyama
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height is 130 m above ground
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 140. m
LENGTH OF DAM : 500. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 122.00 m
MAXIMUM VOLUME OF RESERVOIR : 218. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 5.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Conglomerate, greywacke. Some slate intrusion and a liparite dike.  Jointed rock, extensive consolidation
grouting.
SITE GEOLOGY : Coarse clastic
NOTES ON SEISMICITY AFTER IMPOUNDMENT : none
TYPE OF  RIS : <none>
GEOLOGY REFERENCES : 106,468A
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Bajina Basta

DAM NAME : Bajina Basta
RESERVOIR NAME : Bajina Basta
COUNTRY : Yugoslavia
RIVER : Drina
LOCATION OF CENTER OF RESERVOIR : 43.97N, 19.37E
LOCATION OF DAM : 43.95N, 19.42E
DAM TYPE : Hollow gravity () concrete
DATE DAM COMPLETED : 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam is 89 m above ground
ORIENTATION OF RESERVOIR : N70W
STRUCTURAL HEIGHT OF DAM : 90. (m) above found.
MAXIMUM DEPTH OF RESERVOIR : 80.0 (m) m (from diagram)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 81.00 m
MAXIMUM VOLUME OF RESERVOIR : 340. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 7.0 (km) km
NOTES ON REGIONAL GEOLOGY : In the Dinaride Mountains, which are undergoing uplift relative to the Adriatic coastline due to NE-SW compression. Regional low- and high-angle reverse faults trending northwest, dipping northeast characterize the region.
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam foundation is Paleozoic claystone with a large melaphyre lens. Reservoir is underlain by severely faulted and jointed massive Triassic limestone.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Triassic
DATE OF FIRST SUSPECTED RIS EVENT : Jun-1967
DATE OF LARGEST SUSPECTED RIS EVENT : microearthquakes
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Tremor swarm felt in mid-1967 during initial impoundment. 1967 main hypocenter beneath reservoir at 7 km depth. Although level of macroseismic activity unchanged after inpoundment, very strong temporal and spatial relationship of seismicity to impoundment.
GENERAL NOTES : Data reliability is low to moderate. Few data were obtained. Region of pre-impoundment seismicity.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 64, 106, 370, 418

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Bao


DAM NAME : Bao
RESERVOIR NAME : Embalse del Bao
COUNTRY : Spain
RIVER : Bibey
LOCATION OF CENTER OF RESERVOIR : 42.21N,7.14W
PROVINCE OR REGION : Orense
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : hydropower
NOTES ON DAM : Dam height of 105 m above ground
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 108. m
LENGTH OF DAM : 257. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 90.00 m
MAXIMUM VOLUME OF RESERVOIR : 238. m3x10E6
SURFACE AREA OF RESERVOIR : 8.64 km2
LONGEST DIMENSION OF RESERVOIR : 16.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Dam:  Fine resistant granite intermixed with glandular gneiss and fine-grained gneiss
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 104A,106
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Beas (Pong)

DAM NAME : Beas (Pong)
COUNTRY : India
RIVER : Beas
LOCATION OF CENTER OF RESERVOIR : 31.97N, 76.00E
PROVINCE OR REGION : Himachal Pradesh
DAM TYPE : Gravity
DATE DAM COMPLETED : 1975
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (), hydropower
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 133. m
LENGTH OF DAM : 1951. m
MAXIMUM DEPTH OF RESERVOIR : 88.0 (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 97.80 m
MAXIMUM VOLUME OF RESERVOIR : 8141. m3x10E6
SURFACE AREA OF RESERVOIR : 254.00 km2
LONGEST DIMENSION OF RESERVOIR : 42.0 km
NOTES ON REGIONAL GEOLOGY : Himalayan foothills; upper Siwalik Fm. (Pleistocene), sandstone, claystone, siltstone; Ghamiur syncline and anticlines, axes coalesce to form dome-type structure at dam site.
REGIONAL GEOLOGY : Fine clastic
AGE OF REGIONAL GEOLOGY : Pleistocene
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam: Upper Siwalik Fm. (upper Pleistocene), dipping 20 to 25 degrees N to NE to Recent gravel and fine-grained alluvium
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Pleistocene
PREDOMINANT FAULT TYPE : thrust
NAME OF CLOSEST KNOWN FAULT : Satlitta fault
DISTANCE TO CLOSEST KNOWN FAULT : 1.5 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Pleistocene, possibly Holocene
ARE LOCAL FAULTS ACTIVE? : yes
GEOLOGY REFERENCES : 108,114A,231,237,350,377

**Beauregard**

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DAM NAME : Beauregard
COUNTRY : Italy
RIVER : Dora di Valgrisanche
LOCATION OF CENTER OF RESERVOIR : 45.60N,7.05E
PROVINCE OR REGION : Valle d'Aosta
DAM TYPE : Gravity
DATE DAM COMPLETED : 1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 94 m above ground
STRUCTURAL HEIGHT OF DAM : 132. m
LENGTH OF DAM : 394. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 114.00 m
MAXIMUM VOLUME OF RESERVOIR : 70. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.0 (km) km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : medium
EVIDENCE FOR REGIONAL STRESS REGIME : medium
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : Medium
GEOLOGY REFERENCES : 107
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Bekhme          (Bakhma)


DAM NAME : Bekhme          (Bakhma)
RESERVOIR NAME : Bekhme
COUNTRY : Iraq
RIVER : Greater Zab
DATE DAM COMPLETED : 1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 186. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 156.00 m
MAXIMUM VOLUME OF RESERVOIR : 8300. (m3x10E6) x 10e6 Me3
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 107
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**Belesar**

DAM NAME : Belesar
RESERVOIR NAME : Embalse de Belesar
COUNTRY : Spain
RIVER : Mino
LOCATION OF CENTER OF RESERVOIR : 42.78N, 7.61W
PROVINCE OR REGION : Lugo
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 129 m above ground
ORIENTATION OF RESERVOIR : N25E
STRUCTURAL HEIGHT OF DAM : 132. (m) m above foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 114.00 m
MAXIMUM VOLUME OF RESERVOIR : 600. m3x10E6
SURFACE AREA OF RESERVOIR : 16.00 km2
LONGEST DIMENSION OF RESERVOIR : 50.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Porphyritic granite, fractured on right abutment
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 104A, 106

Benmore

DAM NAME : Benmore
RESERVOIR NAME : Lake Benmore
COUNTRY : New Zealand
RIVER : Waitaki
LOCATION OF CENTER OF RESERVOIR : 44.40S,170.23E
LOCATION OF DAM : 44.56S,170.21E
PROVINCE OR REGION : South Island
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1965
DATE OF START OF FILLING : Dec-1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 110. m
LENGTH OF DAM : 820. m
MAXIMUM DEPTH OF RESERVOIR : 96.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 96.00 m
MAXIMUM VOLUME OF RESERVOIR : 2040. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 65.0 km
NOTES ON REGIONAL GEOLOGY : The Southland syncline is underlain by Paleozoic and Mesozoic sedimentary strata. The syncline is bordered on the northwest by the Alpine fault.
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : Paleozoic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Indurated Permian and Triassic greywacke and argillite.
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Permian, Triassic
NOTES ON FAULTING : The Alpine fault approximately 150 km NW of dam and reservoir. From Cretaceous to Pliocene, RL strike-slip displacement of 480 km. Vertical displacement of 18 km during Pliocene. St. Mary fault located 5 km south of dam.
AZIMUTH OF PREDOMINANT FAULTING : N to NW
DIP OF PREDOMINANT FAULTING : Vertical
PREDOMINANT FRACTURE ORIENTATION : N to NW
NAME OF CLOSEST KNOWN FAULT : St. Mary's fault
DISTANCE TO CLOSEST KNOWN FAULT : 5.0 (km) km.
NOTES ON HYDROLOGY : Relief in excess of 1500 m around reservoir
DEGREE OF TOPOGRAPHIC RELIEF : High () relief
DATE OF FIRST SUSPECTED RIS EVENT : 22-Feb-1965
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 5.0
DATE OF LARGEST SUSPECTED RIS EVENT : 7-Jul-1966 and 6-Apr-1971
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Increase in macroseismic activity near reservoir correlated with initial filling. Activity during 6 years after impoundment three to six times level during 2.5 years prior to impoundment. Microseismic activity related to initial filling and continued after reservoir maintained water level.
GENERAL NOTES : Events are greater than 15 km from dam, none occurred beneath the reservoir. Stations not close enough to accurately locate events.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 4,7,106,203

## Bersimis and Des Roches

DAM NAME : Bersimis and Des Roches
RESERVOIR NAME : Reservoir Pipmuacan (Lac Gouin)
COUNTRY : Canada
RIVER : Bersimis and Des Roches
LOCATION OF CENTER OF RESERVOIR : 49.36N, 69.75W
LOCATION OF DAM : 49.82N, 70.50W () (Bersimis)
PROVINCE OR REGION : Quebec
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1959
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Large reservoir impounded primarily by two dams.  Data on largest dam, Bersimis.  Dam height of 60 m above ground.
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 63. (m) (foundation)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 59.85 m
MAXIMUM VOLUME OF RESERVOIR : 12700. m3x10E6
SURFACE AREA OF RESERVOIR : 1295.00 km2
LONGEST DIMENSION OF RESERVOIR : 86.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 106, 152

Bhakra

DAM NAME : Bhakra
RESERVOIR NAME : Gobind Sagar
COUNTRY : India
RIVER : Sutlej
LOCATION OF CENTER OF RESERVOIR : 31.30N, 76.60E
LOCATION OF DAM : 31.42N, 76.43E
PROVINCE OR REGION : Punjab
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1963
DATE OF START OF FILLING : Jul-1958
RATE OF INITIAL FILLING : 2.40 (m/month) m/month average; half of filling took place in 1959
YEARS FROM BEGINNING TO MAXIMUM FILL : 4.50 (years) years
MAXIMUM RATE OF FILLING : 12.00 (m/month) m/month, 1959
MAXIMUM RATE OF DRAWDOWM : 9.00 (m/month) m/month, early 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower () and irrigation
NOTES ON DAM : L-shaped reservoir, main SE-trending arm parallel to dam. Height above ground 168m.
ORIENTATION OF RESERVOIR : SE
STRUCTURAL HEIGHT OF DAM : 226. m
LENGTH OF DAM : 518. m
MAXIMUM DEPTH OF RESERVOIR : 155.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 155.00 m
MAXIMUM VOLUME OF RESERVOIR : 9868. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 97.0 km
NOTES ON REGIONAL GEOLOGY : Himalayan foothills. Steeply dipping calcareous cemented sedimentary units. Thrust faults and shear zones of post-Miocene age in dam and reservoir area.
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : Tertiary
TECTONIC PROVINCE : Himalayan foothills
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism () and tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Siwaliks, Dagshai, Sabathu and Shali formations -- sandstone, conglomerate, shale, and later Tertiary.
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Plio-Pleistocene
PREDOMINANT FAULT TYPE : thrust
NAME OF CLOSEST KNOWN FAULT : Bhakra, Shali, Nahan
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; beneath dam and reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Pliocene to Holocene
ARE LOCAL FAULTS ACTIVE? : yes
DEGREE OF TOPOGRAPHIC RELIEF : Moderate
GEOLOGY REFERENCES : 106, 228, 378

Bhumiphol (Yanhee)

DAM NAME : Bhumiphol (Yanhee)
COUNTRY : Thailand
RIVER : Ping-Chao Phraya
LOCATION OF CENTER OF RESERVOIR : 17.78N, 98.74E
LOCATION OF DAM : 17.27N, 99.02E
PROVINCE OR REGION : North
DAM TYPE : Concrete gravity () buttress with arch spillway section
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Reservoir trends west for 35 km, then north for 150 km or more
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 154. m
LENGTH OF DAM : 486. m
MAXIMUM DEPTH OF RESERVOIR : 124.0 (m)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 124.00 m
MAXIMUM VOLUME OF RESERVOIR : 12200. m3x10E6
SURFACE AREA OF RESERVOIR : 300.00 (km2)
LONGEST DIMENSION OF RESERVOIR : 207.0 (km)
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 106, 127

Bicaz (Izvorul Muntelui)

DAM NAME : Bicaz (Izvorul Muntelui)
RESERVOIR NAME : Bicaz
COUNTRY : Romania
RIVER : Bistrita
LOCATION OF CENTER OF RESERVOIR : 47.02N, 26.04E
LOCATION OF DAM : 46.95N, 26.08E
PROVINCE OR REGION : Neamt
DAM TYPE : Gravity
DATE DAM COMPLETED : 1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 97 m above ground
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 127. m
LENGTH OF DAM : 430. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 109.00 m
MAXIMUM VOLUME OF RESERVOIR : 1230. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 20.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 107, 125, 166, 368

Bin el Ouidane

DAM NAME : Bin el Ouidane
COUNTRY : Morocco
RIVER : Oued el Abid
LOCATION OF CENTER OF RESERVOIR : 32.09N,6.40W
PROVINCE OR REGION :: Beni-Mellal
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1953
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower () and irrigation
NOTES ON DAM : Dam height of 107.5 m above ground; reservoir extends NE and SE from dam.
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 132. m
LENGTH OF DAM : 290. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 114.50 m
MAXIMUM VOLUME OF RESERVOIR : 1500. m3x10E6
NOTES ON REGIONAL GEOLOGY : Jurassic limestone regionally faulted and folded
REGIONAL GEOLOGY : Carbonate
AGE OF REGIONAL GEOLOGY : Jurassic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Jurassic limestone alternating with marly strata and underlain by thick belt of impervious marls at dam; shallow dip
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Jurassic
DEGREE OF DEFORMATION : Shallow dipping
GEOLOGY REFERENCES : 106,176A

Blowering

DAM NAME : Blowering
RESERVOIR NAME : Lake Blowering
COUNTRY : Australia
RIVER : Tumut
LOCATION OF CENTER OF RESERVOIR : 35.50S, 148.26E
LOCATION OF DAM : 35.40S, 148.25E
DAM TYPE : Earth () fill
DATE DAM COMPLETED : Sep-1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (), irrigation
NOTES ON DAM : Dam height 101 m above ground.
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 112. (m) above found.
LENGTH OF DAM : 808. m
MAXIMUM DEPTH OF RESERVOIR : 95.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 95.00 m
MAXIMUM VOLUME OF RESERVOIR : 1628. m3x10E6
SURFACE AREA OF RESERVOIR : 44.50 (km2) km e2
LONGEST DIMENSION OF RESERVOIR : 25.0 (km) km
NOTES ON REGIONAL GEOLOGY : Snowy Mountains are primarily Paleozoic granitic units intruded into and overlain by Paleozoic rhyolite and Tertiary basalt. Faults and shear zones resulting from regional northwest-southwest- oriented compression include northeast-trending thrust faults and northwest-trending strike-slip faults.
REGIONAL GEOLOGY : Batholithic
AGE OF REGIONAL GEOLOGY : Paleozoic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and reservoir foundation: Dam underlain by sedimentary strata. Reservoir underlain by granite and locally by sedimentary rocks.
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Paleozoic
DATE OF FIRST SUSPECTED RIS EVENT : Jun-1971
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 3.5 (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 6-Jan-1973
NETWORK HISTORY BEFORE RESERVOIR IMPOUNDMENT : A 4-station network of short-period Benioff seismographs was installed in the Snowy Mountains in 1958. An additional station was installed 3 km north of Talbingo Dam in 1969.
NETWORK HISTORY AFTER RESERVOIR IMPOUNDMENT : Three temporary seismograph stations were installed in the Talbingo Dam site area in 1971.
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Considered same RIS case as Talbingo. Increase in macroseismicity and spatial/temporal correlation of microseismicity following impoundment of Talbingo. These two reserviors considered to act as combined influence on local seismicity.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro (); see Talbingo
GEOLOGY REFERENCES : 40, 99, 100, 106, 203, 456, 460, 481

Blue Mesa

DAM NAME : Blue Mesa
RESERVOIR NAME : Blue Mesa
COUNTRY : USA
RIVER : Gunnison
LOCATION OF CENTER OF RESERVOIR : 38.47N, 107.22W
PROVINCE OR REGION : Colorado
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () is principle use
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 119. m
LENGTH OF DAM : 239. m
MAXIMUM DEPTH OF RESERVOIR : 104.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 104.00 m
MAXIMUM VOLUME OF RESERVOIR : 1161. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 30.0 km
NOTES ON REGIONAL GEOLOGY : Volcanic upland
REGIONAL GEOLOGY : Volcanic
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Diorite and metamorphics at dam
SITE GEOLOGY : Metamorphic
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N60W () average
MAXIMUM LENGTH OF FAULTS : 13.00 (km) km with Neogene activity
DOMINANT SIDE UP : S (); south
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Two possible faults through reservoir; upthrown block () of Cimarron fault
NAME OF CLOSEST KNOWN FAULT : Cimarron fault
DISTANCE TO CLOSEST KNOWN FAULT : 10.0 (km) km south
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Offsets Miocene deposits
GEOLOGY REFERENCES : 106, 258

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Bort


DAM NAME : Bort
COUNTRY : France
RIVER : Dordogne
LOCATION OF CENTER OF RESERVOIR : 45.49N,2.52E
LOCATION OF DAM : 45.43N,2.50E
PROVINCE OR REGION : Correze
DAM TYPE : Concrete arch () with gravity secondary dam
DATE DAM COMPLETED : 1951
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 121. (m) above lowest foundation
LENGTH OF DAM : 390. m
MAXIMUM DEPTH OF RESERVOIR : 120.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 120.00 m
MAXIMUM VOLUME OF RESERVOIR : 477. m3x10E6
NOTES ON REGIONAL GEOLOGY : Gneiss and mica schist; buried pre-glacial valley filled with sandy clay alluvium in vicinity of
reservoir
REGIONAL GEOLOGY : Metamorphic
TECTONIC PROVINCE : Massif Central
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Dam:  Gneiss separated from mica schist by one major and two (orthogonal) minor faults.  Gouge zone of soft
clay in portions of foundation; dam built astride fault
SITE GEOLOGY : Metamorphic
NOTES ON FAULTING : Dam built astride fault
DIP OF PREDOMINANT FAULTING : 45SE
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; at dam site
GEOLOGY REFERENCES : 106,176A,468A
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**Bratsk**

DAM NAME : Bratsk
RESERVOIR NAME : Bratskoje Vodochranilisce
COUNTRY : USSR
RIVER : Angara
LOCATION OF CENTER OF RESERVOIR : 56.17N,102.17E
LOCATION OF DAM : 56.08N,101.80E
PROVINCE OR REGION : Irkutsk
DAM TYPE : Earth () buttress with gravity dam at spillways
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Reservoir oriented with one arm to south, main arm to east then south
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 125. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.50 m
MAXIMUM VOLUME OF RESERVOIR : 169400. m3x10E6
SURFACE AREA OF RESERVOIR : 5426.00 km2
LONGEST DIMENSION OF RESERVOIR : 425.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Dense diabase, few fractures
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,152,289

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Brownlee


DAM NAME : Brownlee
RESERVOIR NAME : Brownlee
COUNTRY : USA
RIVER : Snake
LOCATION OF CENTER OF RESERVOIR : 44.63N,117.10W
LOCATION OF DAM : 44.83N,116.90W
PROVINCE OR REGION : Idaho
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1959
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (), flood control
NOTES ON DAM : Dam height of 93 m above ground
ORIENTATION OF RESERVOIR : S70W
STRUCTURAL HEIGHT OF DAM : 120. m
LENGTH OF DAM : 518. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 108.00 m
MAXIMUM VOLUME OF RESERVOIR : 1670. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 65.0 (km) km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 107
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Bukhtarma

DAM NAME : Bukhtarma
COUNTRY : USSR
RIVER : Irtish
LOCATION OF CENTER OF RESERVOIR : 48.95N, 83.68E
LOCATION OF DAM : 49.72N, 83.33E
PROVINCE OR REGION : Altay
DAM TYPE : Hollow gravity
DATE DAM COMPLETED : 1960
DATE OF START OF FILLING : Filling began in Apr-1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Increases existing lake
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 90. m
LENGTH OF DAM : 380. m
MAXIMUM DEPTH OF RESERVOIR : 67.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 67.00 m
MAXIMUM VOLUME OF RESERVOIR : 53000. m3x10E6
SURFACE AREA OF RESERVOIR : 5500.00 (km2) (includes Lake Zayzan, 1900 km sq.)
LONGEST DIMENSION OF RESERVOIR : 152.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Gabbro and amphibolite
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106, 152, 289, 330A

Cabin Creek

DAM NAME : Cabin Creek
RESERVOIR NAME : Cabin Creek
COUNTRY : USA
RIVER : Clear Creek
LOCATION OF CENTER OF RESERVOIR : 39.62N,105.72W
LOCATION OF DAM : 39.63N,105.71W
PROVINCE OR REGION : Colorado
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1967
NOTES ON HISTORY OF IMPOUNDMENT : Lower Cabin Creek reservoir was filled in Summer 1966; upper Cabin Creek reservoir was filled in March-April 1967.
DATE OF START OF FILLING : Mar-1967
YEARS FROM BEGINNING TO MAXIMUM FILL : 0.18 (years) years; two months
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (); pumped storage
NOTES ON DAM : Cabin Creek consists of two small reservoirs high in the Rocky Mountains
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 49. m
LENGTH OF DAM : 454. m
MAXIMUM DEPTH OF RESERVOIR : 46.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 46.00 m
MAXIMUM VOLUME OF RESERVOIR : 18. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 1.0 (km) km
NOTES ON REGIONAL GEOLOGY : Precambrian metamorphic and plutonic rocks in the Front Range of the Rocky Mountains. The Front Range typically is bordered on the east and west by north-trending, steeply dipping reverse faults. The Front Range is uplifted relative to regions to the east and west. Uplift caused by east-west compression.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Pre-Cambrian
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
DEGREE OF TOPOGRAPHIC RELIEF : high
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Increase in microseismic recordings in 1967 and 1968 due to blasting for highway construction, unrelated to reservoir impoundment.
GENERAL NOTES : Data reliability is low. Events apparently correlate with nearby blasting operations.
RIS CATEGORY : Not RIS
GEOLOGY REFERENCES : 106,150,209A,288,331,417,418

## Cabora Bassa

DAM NAME : Cabora Bassa
COUNTRY : Mozambique
RIVER : Zambese
LOCATION OF CENTER OF RESERVOIR : 15.64S,31.91E
LOCATION OF DAM : 15.57S,32.72E
PROVINCE OR REGION : Near Tete
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1974
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 171. (m) (height above lowest foundation)
MAXIMUM DEPTH OF RESERVOIR : 141.0 (m) calculated from scale drawing
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 141.00 m
MAXIMUM VOLUME OF RESERVOIR : 63000. m3x10E6
SURFACE AREA OF RESERVOIR : 2700.00 km2
LONGEST DIMENSION OF RESERVOIR : 250.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
SITE GEOLOGY : Metamorphic () (gneiss)
AGE OF SITE GEOLOGY : Pre-Cambrian
GEOLOGY REFERENCES : 105,107,108,277,433

Cabril

DAM NAME : Cabril
RESERVOIR NAME : Cabril
COUNTRY : Portugal
RIVER : Zezere
LOCATION OF CENTER OF RESERVOIR : 39.97N, 8.05W
PROVINCE OR REGION : Castelo Branco
DAM TYPE : Cupola gravity
DATE DAM COMPLETED : 1954
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 132 m above ground
STRUCTURAL HEIGHT OF DAM : 136. m
LENGTH OF DAM : 290. m
MAXIMUM DEPTH OF RESERVOIR : Approximately 124.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 124.00 m
MAXIMUM VOLUME OF RESERVOIR : 700. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Granite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106, 289, 367

Cajuru

DAM NAME : Cajuru
COUNTRY : Brazil
RIVER : Para
LOCATION OF CENTER OF RESERVOIR : 20.30S, 44.70W
LOCATION OF DAM : 20.23S, 44.75W
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1953
DATE OF START OF FILLING : 1954
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 23. m
LENGTH OF DAM : 438. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 20.70 m
MAXIMUM VOLUME OF RESERVOIR : 192. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 18.0 (km) km
NOTES ON REGIONAL GEOLOGY : Precambrian gneiss with gabbro and diabase dikes. Locally beds of the Minas Series of quartzite and schist are present. Vertical fractures trend predominately N65W and N20E. Faults (type and age not described) are present.
REGIONAL GEOLOGY : metamorphic
AGE OF REGIONAL GEOLOGY : Pre Cambrian
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Precambrian gneiss with gabbro and diabase dikes. Vertical fractures trend predominately N65W and N20E.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Pre Cambrian
DATE OF FIRST SUSPECTED RIS EVENT : Dec-1970
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No seismicity reported for 16 years after impoundment. 1970-1971 seismicity not clearly related to water level fluctuations although epicenters probably near reservior. Unclear influence of reservior on seismicity.
GENERAL NOTES : Data reliability is low. Few data were obtained. Reservoir impounded 17 years prior to reports of seismic activity. Shallow, small reservoir.
RIS CATEGORY : Questionable
TYPE OF RIS : macro
GEOLOGY REFERENCES : 67, 106

## Camarillas

DAM NAME : Camarillas
COUNTRY : Spain
RIVER : Mundo
LOCATION OF CENTER OF RESERVOIR : 38.36N, 1.65W
LOCATION OF DAM : 38.33N, 1.66W
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1960
DATE OF START OF FILLING : Nov-1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Dam height of 36 m above ground.
ORIENTATION OF RESERVOIR : NNE
STRUCTURAL HEIGHT OF DAM : 49. (m) m above foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 43.65 m
MAXIMUM VOLUME OF RESERVOIR : 37. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 8.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Jurassic and Cretaceous limestone dome cut by the Mundo River. Local diapiric structures reported.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Cretaceous
NOTES ON FAULTING : Quaternary normal faults. Location and orientation not obtained.
PREDOMINANT FAULT TYPE : Normal
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary
DATE OF FIRST SUSPECTED RIS EVENT : 16-Mar-1961
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.1 (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 15-Apr-1964
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Good spatial and temporal association of macroseismicity with initial impoundment. Activity began when reservoir reached 2/3 maximum water depth, correlated with peaks in cyclic loading history. Activity ceased after water level stabilized and reduced.
GENERAL NOTES : Data reliability is low. Few data were obtained.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 64, 72A, 106, 393, 408

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Cancano


DAM NAME : Cancano
RESERVOIR NAME : Lago di Cancano
COUNTRY : Italy
RIVER : Adda
LOCATION OF CENTER OF RESERVOIR : 46.52N,10.30E
PROVINCE OR REGION : Lombardia, Sondrio
DAM TYPE : Concrete arch () with gravity secondary dam
DATE DAM COMPLETED : 1955
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 124.5 m above ground
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 136. m
LENGTH OF DAM : 390. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 118.00 m
MAXIMUM VOLUME OF RESERVOIR : 123. m3x10E6
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Limestone
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 106,289
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Canelles

DAM NAME : Canelles
RESERVOIR NAME : Embalse de Canelles
COUNTRY : Spain
RIVER : Noguera Ribargozana
LOCATION OF CENTER OF RESERVOIR : 42.03N, 0.65E
LOCATION OF DAM : 41.97N, 0.62E
PROVINCE OR REGION : Lerida
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1960
DATE OF START OF FILLING : Oct-1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 135 m above ground
STRUCTURAL HEIGHT OF DAM : 150. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 132.00 m
MAXIMUM VOLUME OF RESERVOIR : 678. m3x10E6
SURFACE AREA OF RESERVOIR : 16.30 km2
LONGEST DIMENSION OF RESERVOIR : 21.0 km
NOTES ON REGIONAL GEOLOGY : Cretaceous marls, marly sandstone, and limestone (karstitic)
REGIONAL GEOLOGY : Carbonate
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : NW-SE anticline at dam, syncline in reservoir
SITE GEOLOGY : Carbonate
DATE OF FIRST SUSPECTED RIS EVENT : 9-Jun-1962
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.7 (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 9-Jun-1962
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Macroseismic event has good spatial and temporal association with initial impoundment.
GENERAL NOTES : Data reliability is low.  Few data were obtained.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 64, 72A, 106, 175, 203, 331, 393

Carters Main

DAM NAME : Carters Main
RESERVOIR NAME : Carters Lake
COUNTRY : USA
RIVER : Coosawattee
LOCATION OF CENTER OF RESERVOIR : 34.62N,85.37W
LOCATION OF DAM : 34.62N,85.33W
PROVINCE OR REGION : Georgia
DAM TYPE : Earth () and rockfill
DATE DAM COMPLETED : 1974
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N60E
STRUCTURAL HEIGHT OF DAM : 141. (m) above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 126.90 m
MAXIMUM VOLUME OF RESERVOIR : 465. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 7.0 (km) km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics (), focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 107,108

Castelo de Bode

DAM NAME : Castelo de Bode
RESERVOIR NAME : Barragem do Castelo de Bode
COUNTRY : Portugal
RIVER : Zezere
LOCATION OF CENTER OF RESERVOIR : 39.69N, 8.23W
PROVINCE OR REGION : Santarem
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1951
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 109 m above ground
ORIENTATION OF RESERVOIR : N10E
STRUCTURAL HEIGHT OF DAM : 115. m
LENGTH OF DAM : 402. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 103.50 m
MAXIMUM VOLUME OF RESERVOIR : 1100. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Micaschists dipping steeply upstream, locally phyllitic or quartzose; schistosity perpendicular to river, plunging upstream
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106, 152, 289

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Cethana


DAM NAME : Cethana
COUNTRY : Australia
RIVER : Forth
LOCATION OF CENTER OF RESERVOIR : 41.55S,146.15E
PROVINCE OR REGION : Tasmania
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1971
DATE OF START OF FILLING : Began 1971
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (); normal operating range 6 m
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 110. m
MAXIMUM DEPTH OF RESERVOIR : 94.5 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 94.50 m
MAXIMUM VOLUME OF RESERVOIR : 178. m3x10E6
SURFACE AREA OF RESERVOIR : 5.00 km2
LONGEST DIMENSION OF RESERVOIR : 30.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Quartzite and conglomerate; shears, joints, faults, on anticline; weak bedding planes
SITE GEOLOGY : Metamorphic
PREDOMINANT FAULT TYPE : Reverse
DIP OF PREDOMINANT FAULTING : N (); north-dipping
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block
GEOLOGY REFERENCES : 62,107,108,299
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Charvak

DAM NAME : Charvak
COUNTRY : USSR
RIVER : Chirchik (junction Chatkal and Pskem)
PROVINCE OR REGION : Uzbekistan
DAM TYPE : Earth
DATE DAM COMPLETED : 1970
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 168. (m) above lowest foundation
LENGTH OF DAM : 764. m
MAXIMUM DEPTH OF RESERVOIR : 130.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 130.00 m
MAXIMUM VOLUME OF RESERVOIR : 2000. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Paleozoic limestone, tectonic fissures, syncline
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Paleozoic
GEOLOGY REFERENCES : 106,330A

Chirkey

DAM NAME : Chirkey
COUNTRY : USSR
RIVER : Sulak
PROVINCE OR REGION : near Makhackula, North Caucasas
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1975
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 233. m
LENGTH OF DAM : 338. m
MAXIMUM DEPTH OF RESERVOIR : 205.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 205.00 m
MAXIMUM VOLUME OF RESERVOIR : 2780. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Limestone, moderately to highly jointed
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 60,107,108

Chivor

DAM NAME : Chivor
COUNTRY : Colombia
RIVER : Bata
PROVINCE OR REGION : near Guateque, Boyaca province
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1975
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 237. m
LENGTH OF DAM : 280. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 213.30 m
MAXIMUM VOLUME OF RESERVOIR : 815. m3x10E6
NOTES ON REGIONAL GEOLOGY : Eastern Cordillera of the Andes. Quartzite, phyllite, and locally shale. Faults and shear zones in the dam vicinity.
REGIONAL GEOLOGY : Metamorphic
TECTONIC PROVINCE : Andes
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
DEGREE OF TOPOGRAPHIC RELIEF : high
GEOLOGY REFERENCES : 107, 108

Clark Hill

DAM NAME : Clark Hill
RESERVOIR NAME : Clark Hill
COUNTRY : USA
RIVER : Savannah
LOCATION OF CENTER OF RESERVOIR : 33.85N, 82.38W
LOCATION OF DAM : 33.66N, 82.20W
PROVINCE OR REGION : Georgia and South Carolina
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1952
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Hydropower () is first listing.
NOTES ON DAM : Dam height is 52 m above ground. Reservoir has inverted L shape, with smaller arm oriented southwest.
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 60. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 54.00 m
MAXIMUM VOLUME OF RESERVOIR : 3517. m3x10E6
SURFACE AREA OF RESERVOIR : 372.00 (km2) sq km
LONGEST DIMENSION OF RESERVOIR : 53.0 (km) km
NOTES ON REGIONAL GEOLOGY : Precambrian and Paleozoic metamorphic units of the Piedmont province. Low to high grade metamorphic suites are highly deformed as a result of Precambrian and Paleozoic orogenic events.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Paleozoic
TECTONIC PROVINCE : Piedmont
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam is underlain by Paleozoic gneiss. Reservoir is underlain by the gneiss, Paleozoic argillite, Paleozoic muscovite schist, and locally by Mesozoic gabbro.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Paleozoic
NOTES ON FAULTING : Fault plane solutions for 1974 aftershock sequence suggest left slip along a plane oriented N40E, 82SE, and thrust fault motion along a plane oriented N34E, 70SE. No additional data were obtained.
DATE OF FIRST SUSPECTED RIS EVENT : 2-Aug-1974
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.3 Mb (NOAA) This is largest post-filling event; influence of reservoir on this earthquake is unclear.
DATE OF LARGEST SUSPECTED RIS EVENT : 2-Aug-1974
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Microseismicity recorded in 1974 and 1975 clearly related to changes in water level. No change in macroseismicity following impoundment. No information of microseismicity between impoundment and mid-1974.
GENERAL NOTES : Weak case of reservoir induced seismicity. Absence of information on microseismic activity for more than 20 years after impoundment. Historic earthquakes have been located near the dam site.
RIS CATEGORY : Accepted
TYPE OF RIS : micro (), questionable macro
GEOLOGY REFERENCES : 106, 445, 446

DAM NAME : Contra
RESERVOIR NAME : Lago di Vogorno
COUNTRY : Switzerland
RIVER : Verzasca
LOCATION OF CENTER OF RESERVOIR : 46.23N, 8.83E
LOCATION OF DAM : 46.20N, 8.85E
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1965
DATE OF START OF FILLING : Aug-1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 220. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 190.00 m
MAXIMUM VOLUME OF RESERVOIR : 86. m3x10E6
SURFACE AREA OF RESERVOIR : 233.00 km2
LONGEST DIMENSION OF RESERVOIR : 4.8 km
NOTES ON REGIONAL GEOLOGY : In the Simplon-Ticino nappes within the Pennine Alps. Characterized by northward to northwestward thrust nappes resulting from Mesozoic and Cenozoic orogenic events. Rock units are principally Paleozoic crystalline rocks, particularly gneiss.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : late Paleozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Gneiss; folded and faulted. The gneiss is described as being mechanically competent.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Permian
NOTES ON FAULTING : Two faults near Berzona in the dam and reservoir region. Age and type of most recent displacement were not obtained. A fault beneath the dam is described as being healed. Block faulting of post-Miocene to Mesozoic age is present in the region.
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : N85W
MAXIMUM LENGTH OF FAULTS : 27.00 (km) km
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Most of reservoir within upthrown block
NAME OF CLOSEST KNOWN FAULT : Unnamed
DISTANCE TO CLOSEST KNOWN FAULT : 1.0 (km) km
PERMEABILITY OF ROCKS : Inferred low () permeability in gneiss bedrock.
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : May-1965
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Microseismicity near reservoir associated with rapid initial filling; additional activity after filling may be related to water level fluctuations. After reservoir drained and refilled, seismic activity returned to pre-impoundment levels
GENERAL NOTES . Data reliability is moderate. Baseline data not obtained; pre-impoundment seismicity not obtained; interpretations strongly suggest temporal and spatial relationships of seismicity during initial impoundment.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 64, 102, 106, 176, 203, 280, 331, 434

Cougar

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DAM NAME : Cougar
RESERVOIR NAME : Cougar
COUNTRY : USA
RIVER : South Fork MacKenzie
LOCATION OF CENTER OF RESERVOIR : 44.10N,122.20W
PROVINCE OR REGION : Oregon
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Flood control () is listed first
NOTES ON DAM : Dam height of 127 m above ground
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 136. m
LENGTH OF DAM : 527. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 122.40 m
MAXIMUM VOLUME OF RESERVOIR : 270. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 8.4 (km) km
TECTONIC PROVINCE : Cascades
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Tuff, sandstone, and basalts, overlain by alluvial deposits
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Tertiary
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N () to NN
MAXIMUM LENGTH OF FAULTS : 20.00 (km) km
NAME OF CLOSEST KNOWN FAULT : Sweet Home fault
DISTANCE TO CLOSEST KNOWN FAULT : 45.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : late Tertiary
GEOLOGY REFERENCES : 106,224,289,337
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DAM NAME : Coyote Valley
RESERVOIR NAME : Lake Mendocino
COUNTRY : USA
RIVER : East Fork Russian River
LOCATION OF CENTER OF RESERVOIR : 39.23N,123.17W
LOCATION OF DAM : 39.20N,123.18W
PROVINCE OR REGION : California
DAM TYPE : Earth
DATE DAM COMPLETED : 1959
DATE OF START OF FILLING : Jan-1959
RATE OF INITIAL FILLING : 5.50 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 0.29 (years) years
MAXIMUM RATE OF FILLING : 8.80 (m/month) m/month from Dec. 1977-Jan. 1978
MAXIMUM RATE OF DRAWDOWM : 3.00 (m/month) m/month in 1977
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control ();  maximum fluctuation of 10.7 m before 1976
NOTES ON DAM : Water depth of 22 m calculated from water level data, while depth of 30 m calculated from topo map.
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 50. m
LENGTH OF DAM : 1070. m
MAXIMUM DEPTH OF RESERVOIR : 22.0 (m) (from water level data)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 22.00 m
MAXIMUM VOLUME OF RESERVOIR : 151. m3x10E6
SURFACE AREA OF RESERVOIR : 7.90 km2
LONGEST DIMENSION OF RESERVOIR : 5.5 km
NOTES ON REGIONAL GEOLOGY : Cretaceous - Jurassic Franciscan Assemblage of Coast Ranges province.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Cretaceous
TECTONIC PROVINCE : Coast Ranges
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON FAULTING : EQ focal mechanisms indicate RL reverse slip for earthquakes on the Maacama fault, but the fault is mapped as
strike-slip
PREDOMINANT FAULT TYPE : Right-slip
AZIMUTH OF PREDOMINANT FAULTING : N30W
MAXIMUM LENGTH OF FAULTS : 120.00 (km) km
DOMINANT SIDE UP : E (); east
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block
NAME OF CLOSEST KNOWN FAULT : Maacama fault
DISTANCE TO CLOSEST KNOWN FAULT : 1.3 (km) km west
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Holocene (Fault creep)
RATE OF SLIP ON LOCAL FAULTS : 2.0000 (cm/yr) mm/yr fault creep
ARE LOCAL FAULTS ACTIVE? : Yes
SEISMICITY ASSOCIATED WITH FAULTS IN LOCAL AREA? : Yes
DATE OF FIRST SUSPECTED RIS EVENT : 5-Apr-1959
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 5.2
DATE OF LARGEST SUSPECTED RIS EVENT : 6-Jun-1962
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Although level of macroseismic activity unchanged following impoundment, post-impoundment
earthquakes near reservoir have good association with initial impoundment and major changes in water level.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
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GEOLOGY REFERENCES : 106, 121, 235, 457

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Curnera


DAM NAME : Curnera
COUNTRY : Switzerland
RIVER : Rein de Curnera
LOCATION OF CENTER OF RESERVOIR : 46.63N,8.71E
PROVINCE OR REGION : Grischun
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 152. (m) above lowest foundation
LENGTH OF DAM : 340. m
MAXIMUM DEPTH OF RESERVOIR : 126.0 (m) (calculated from topographic map)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 126.00 m
MAXIMUM VOLUME OF RESERVOIR : 40. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 2.1 (km) (from topo. map)
NOTES ON REGIONAL GEOLOGY : Paleozoic St. Gotthard massif
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Paleozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Permo-Carboniferous gneiss and mica schist
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Carboniferous
MAXIMUM LENGTH OF FAULTS : 80.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : less than 1.0 (km) km
GEOLOGY REFERENCES : 106,440A,440B
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Daniel Johnson (Manicouagan 5)

DAM NAME : Daniel Johnson (Manicouagan 5)

RESERVOIR NAME : Manicouagan

COUNTRY : Canada

RIVER : Manicouagan

LOCATION OF CENTER OF RESERVOIR : 51.13N,68.64W

LOCATION OF DAM : 50.65N,68.74W

PROVINCE OR REGION : Quebec

DAM TYPE : Concrete multi-arch

DATE DAM COMPLETED : 1968

EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower

NOTES ON DAM : Reservoir has long north-extending arm into circle around impact crater. Dam height of 164 m above ground.

ORIENTATION OF RESERVOIR : N

STRUCTURAL HEIGHT OF DAM : 214. (m) (ht. above foundation)

LENGTH OF DAM : 1314. m

MAXIMUM DEPTH OF RESERVOIR : 152.0 (m) (calculated from drawing)

RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 152.00 m

MAXIMUM VOLUME OF RESERVOIR : 141851. m3x10E6

SURFACE AREA OF RESERVOIR : 2070.00 km2

LONGEST DIMENSION OF RESERVOIR : 140.0 km

NOTES ON REGIONAL GEOLOGY : Grenville Province of Canadian Shield. Reservoir drowns peripheral trough of Manicouagan impact crater, large (65-km diameter) meteorite impact crater, 214 m.y. old; melt rocks, gneiss (transitional from regional bedrock), garnet anorthosite. Regional basement of gneiss, charnokitic gneiss, and gabbro.

REGIONAL GEOLOGY : Metamorphic

AGE OF REGIONAL GEOLOGY : Precambrian

TECTONIC PROVINCE : Canadian Shield

REGIONAL STRESS REGIME : Compressional

EVIDENCE FOR REGIONAL STRESS REGIME : tectonics

CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium

NOTES ON SITE GEOLOGY : Dam: Granitoid gneiss and hornblende/biotite gneiss; shear zones; overlying thin alluvium and glacial drift. Shear zones and joints.

SITE GEOLOGY : Metamorphic

AGE OF SITE GEOLOGY : Triassic (210 m.y. BP)

ORIENTATION OF STRUCTURAL GRAIN : Circular around impact melt

DEGREE OF DEFORMATION : Strongly deformed

NOTES ON FAULTING : Faults through dam site are part of regional basement faulting. Circular fault under main reservoir bounds impact crater.

AZIMUTH OF PREDOMINANT FAULTING : NE (); N25E to N55E at dam

DIP OF PREDOMINANT FAULTING : 85W

GEOLOGY REFERENCES : 107,187,303,363

Danjiangkou (Tankiangkow)

DAM NAME : Danjiangkou (Tankiangkow)
COUNTRY : China (PRC)
RIVER : Han Jiang (Han Shui)
LOCATION OF CENTER OF RESERVOIR : 32.69N, 111.08E
LOCATION OF DAM : 32.55N, 111.50E
PROVINCE OR REGION : Hubei (Hupeh, nr. Xiangfan)
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1974
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
STRUCTURAL HEIGHT OF DAM : 97. (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 87.30 m
MAXIMUM VOLUME OF RESERVOIR : 20900. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Diorite and metamorphic shale
GEOLOGY REFERENCES : 108, 289, 418

Dartmouth

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DAM NAME : Dartmouth
COUNTRY : Australia
RIVER : Mitta-Mitta
LOCATION OF CENTER OF RESERVOIR : 36.62S,147.68E
PROVINCE OR REGION : Victoria
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1978
DATE OF START OF FILLING : 1977
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (), hydropower
STRUCTURAL HEIGHT OF DAM : 180. m
LENGTH OF DAM : 670. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 162.00 m
MAXIMUM VOLUME OF RESERVOIR : 4000. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 30.0 km
NOTES ON REGIONAL GEOLOGY : Lachlan geosyncline in Snowy Mountains. Includes gneiss
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : late Paleozoic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Snowy River Devonian Volcanics, Silurian granite, and Ordovician metamorphics in reservoir area. Granite
gneiss at damsite, jointed.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : late Paleozoic
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : NE (); northeast
DOMINANT SIDE UP : NW (); northwest
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary
GEOLOGY REFERENCES : 108,297,481
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Derbendikhan

DAM NAME : Derbendikhan
COUNTRY : Iraq
RIVER : Diyala
LOCATION OF CENTER OF RESERVOIR : 35.17N,45.82E
LOCATION OF DAM : 35.12N,45.72E
PROVINCE OR REGION : Sulaymaniya
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Y-shaped reservoir
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 128. (m) above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 115.20 m
MAXIMUM VOLUME OF RESERVOIR : 3000. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 26.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Marl, sandstone, limestone, and conglomerate, thick sedimentary layer
SITE GEOLOGY : Coarse clastic
GEOLOGY REFERENCES : 106,289

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Detroit


DAM NAME : Detroit
RESERVOIR NAME : Detroit
COUNTRY : USA
RIVER : N. Santiam
LOCATION OF CENTER OF RESERVOIR : 44.72N,122.18W
LOCATION OF DAM : 44.72N,122.25W
PROVINCE OR REGION : Oregon
DAM TYPE : Gravity
DATE DAM COMPLETED : 1953
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Flood control () is first use listed.
NOTES ON DAM : Dam height of 116 m above ground
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 141. (m) above foundations
LENGTH OF DAM : 466. m
MAXIMUM DEPTH OF RESERVOIR : 110.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 110.00 m
MAXIMUM VOLUME OF RESERVOIR : 561. m3x10E6
SURFACE AREA OF RESERVOIR : 17.00 km2
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Andesite and diorite
SITE GEOLOGY : Volcanic
NOTES ON FAULTING : Note:  no major faults in immediate reservoir area.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : NW ()-trending
MAXIMUM LENGTH OF FAULTS : 80.00 (km) km
NAME OF CLOSEST KNOWN FAULT : Mt. Jefferson fault
DISTANCE TO CLOSEST KNOWN FAULT : NW end of fault 30.0 (km) km east of reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary
GEOLOGY REFERENCES : 106,224,337
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Dez (Mohammed Reza Shah Pahlavi)

DAM NAME : Dez (Mohammed Reza Shah Pahlavi)
COUNTRY : Iran
RIVER : Dez
LOCATION OF CENTER OF RESERVOIR : 32.72N, 48.58E
LOCATION OF DAM : 32.62N, 48.47E
PROVINCE OR REGION : Khouzestan
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; principle uses include Irrigation () and Flood control.
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 203. m
LENGTH OF DAM : 212. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 173.00 m
MAXIMUM VOLUME OF RESERVOIR : 3340. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 31.0 km
NOTES ON REGIONAL GEOLOGY : Eastern flank of the Zagros Mts. Deformed late Cenozoic sedimentary units.
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : late Tertiary
TECTONIC PROVINCE : Zagros belt
REGIONAL STRESS REGIME : Compressional (); principal compressive stress oriented N10E; horizontal component of slip vector N10W.
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON FAULTING : Major fault system is the Zagros thrust, with right-slip component. Dorud fault (in this zone; 70 km NE of reservoir) had right-slip in 1909. Dezful fault is local to reservoir.
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : NW
DIP OF PREDOMINANT FAULTING : N20E to N70E () NE
MAXIMUM LENGTH OF FAULTS : 15.00 km
DOMINANT SIDE UP : NE
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block (); note that reservoir is on downthrown block of Main Zagros fault.
NAME OF CLOSEST KNOWN FAULT : Fault near Dezful, unnamed
DISTANCE TO CLOSEST KNOWN FAULT : 20.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : pre-Quaternary
ARE LOCAL FAULTS ACTIVE? : No (); none documented
DEGREE OF TOPOGRAPHIC RELIEF : Moderate
GEOLOGY REFERENCES : 46, 106, 341, 436, 499

Diablo

DAM NAME : Diablo
RESERVOIR NAME : Diablo Lake
COUNTRY : USA
RIVER : Skagit
LOCATION OF CENTER OF RESERVOIR : 48.72N,121.13W
PROVINCE OR REGION : Washington
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1929
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 119. (m) above lowest foundation
LENGTH OF DAM : 360. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 101.00 m
MAXIMUM VOLUME OF RESERVOIR : 111. m3x10E6
SURFACE AREA OF RESERVOIR : 4.40 km2
LONGEST DIMENSION OF RESERVOIR : 5.0 (km) km
TECTONIC PROVINCE : North Cascades
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Granite and gneiss
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106

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Djiroft         (Jiroft)


DAM NAME : Djiroft         (Jiroft)
COUNTRY : Iran
RIVER : Halil Rud
LOCATION OF DAM : 28.50N,57.80E
PROVINCE OR REGION : Kerman
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1976
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 133. (m) above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 115.00 m
MAXIMUM VOLUME OF RESERVOIR : 430. m3x10E6
NOTES ON REGIONAL GEOLOGY : Highly folder and faulted sediments
TECTONIC PROVINCE : Makran tectonic zone
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
PREDOMINANT FAULT TYPE : Normal right (), noraml, right-slip
AZIMUTH OF PREDOMINANT FAULTING : N20W to N5E
DIP OF PREDOMINANT FAULTING : Vertical
MAXIMUM LENGTH OF FAULTS : 210.00 (km) km (Sabzevaran); 310 km (Sarduiyeh/Jiroft)
DOMINANT SIDE UP : W (); west
PREDOMINANT FRACTURE ORIENTATION : N10W to N10E
NAME OF CLOSEST KNOWN FAULT : 10 km east
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Pre-Quaternary for Sabzevaran, Quarternary on Sarduiyeh fault
GEOLOGY REFERENCES : 46,107,108
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Dokan          (Dukan)


DAM NAME : Dokan            (Dukan)
RESERVOIR NAME : Dukan
COUNTRY : Iraq
RIVER : Lesser Zab
LOCATION OF CENTER OF RESERVOIR : 36.07N,44.97E
LOCATION OF DAM : 35.95N,44.97E
PROVINCE OR REGION : Sulaymaniya
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1959
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 116. (m) above lowest foundation
MAXIMUM DEPTH OF RESERVOIR : 111.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 111.00 m
MAXIMUM VOLUME OF RESERVOIR : 6800. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 29.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Reservoir:  1000 m marl, 123 m limestone, 1 m shale, 3 m limestone, 130+ m dolomite, all Cretaceous; dam
founded on approximately horizontal dolomite
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Cretaceous
DEGREE OF DEFORMATION : flatlying
GEOLOGY REFERENCES : 106,468A
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Dworshak

DAM NAME : Dworshak
RESERVOIR NAME : Dworshak Reservoir
COUNTRY : USA
RIVER : North Fork Clearwater
LOCATION OF CENTER OF RESERVOIR : 46.62N, 116.07W
LOCATION OF DAM : 46.52N, 116.30W
PROVINCE OR REGION : Idaho
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1974
DATE OF START OF FILLING : 1971
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 216. m
LENGTH OF DAM : 1002. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 186.00 m
MAXIMUM VOLUME OF RESERVOIR : 4259. m3x10E6
SURFACE AREA OF RESERVOIR : 69.00 km2
LONGEST DIMENSION OF RESERVOIR : 85.0 km
NOTES ON REGIONAL GEOLOGY : Idaho Batholith. Precambrian metasedimentary and Tertiary volcanic rocks. Batholith typified by normal faults.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Precambrian
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Foliated gneiss. Foliations dipping steeply northeast.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : PreCambrian
ORIENTATION OF STRUCTURAL GRAIN : NE
GEOLOGY REFERENCES : 92, 107, 108

## El Atazar

DAM NAME : El Atazar
RESERVOIR NAME : Embalse del Atazar
COUNTRY : Spain
RIVER : Lozoya
LOCATION OF CENTER OF RESERVOIR : 40.90N,3.48W
PROVINCE OR REGION : Madrid
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1972
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply
NOTES ON DAM : Reservoir oriented N and NE from dam
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 134. m
MAXIMUM DEPTH OF RESERVOIR : 120.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 120.00 m
MAXIMUM VOLUME OF RESERVOIR : 426. m3x10E6
SURFACE AREA OF RESERVOIR : 12.30 km2
LONGEST DIMENSION OF RESERVOIR : 17.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Silurian slates, two systems of fractures parallel to mountain side, one other system sub-horizontal and one other system sub- vertical.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Silurian
GEOLOGY REFERENCES : 104A,106

El Chocon

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DAM NAME : El Chocon
RESERVOIR NAME : Ezequil
COUNTRY : Argentia
RIVER : Limay
LOCATION OF CENTER OF RESERVOIR : 39.44S,68.93W
LOCATION OF DAM : 39.22S,69.68W
PROVINCE OR REGION : Neuquen/Rio Negro
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 74. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 70.30 m
MAXIMUM VOLUME OF RESERVOIR : 20200. m3x10E6
SURFACE AREA OF RESERVOIR : 816.00 km2
LONGEST DIMENSION OF RESERVOIR : 72.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Hard red sandstone, some lenses of argillite clay
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Cretaceous
GEOLOGY REFERENCES : 104,107,108
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El Grado

DAM NAME : El Grado
RESERVOIR NAME : El Grado
COUNTRY : Spain
RIVER : Cinca
LOCATION OF CENTER OF RESERVOIR : 42.38N,0.17E
LOCATION OF DAM : 42.30N,0.20E
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1969
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 88 m above ground
ORIENTATION OF RESERVOIR : NNW
STRUCTURAL HEIGHT OF DAM : 130. m
LENGTH OF DAM : 400. m
MAXIMUM DEPTH OF RESERVOIR : 85.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 85.00 m
MAXIMUM VOLUME OF RESERVOIR : 400. m3x10E6
SURFACE AREA OF RESERVOIR : 13.00 km2
LONGEST DIMENSION OF RESERVOIR : 13.0 km
TECTONIC PROVINCE : Pyrenees
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Oligocene conglomerate overlying limestone and Jurassic marl. Conglomerate nearly horizontal. Eocene yellow marls under stream bed.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Tertiary
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No good spatial or temporal relationship of post-impoundment seismicity to reservoir.
GENERAL NOTES : Data reliability is low. Few data were obtained.
RIS CATEGORY : Not RIS
GEOLOGY REFERENCES : 72A,107,118,289,408,418

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El Infiernillo


DAM NAME : El Infiernillo
RESERVOIR NAME : Presa del Infiernillo
COUNTRY : Mexico
RIVER : Balsas
LOCATION OF CENTER OF RESERVOIR : 18.58N,101.75W
LOCATION OF DAM : 18.27N,101.90W
PROVINCE OR REGION : Michoacan
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public Water supply
NOTES ON DAM : T-shaped reservoir
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 140. (m) above lowest foundation
LENGTH OF DAM : 345. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 126.00 m
MAXIMUM VOLUME OF RESERVOIR : 9340. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 84.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Tertiary conglomerate with contact metamorphism around intrusive diorite. North-south fractures related to
intrusive
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Tertiary
GEOLOGY REFERENCES : 106,228A
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El Novillo (Plutarco Elias Calles)

DAM NAME : El Novillo (Plutarco Elias Calles)
RESERVOIR NAME : Novillo
COUNTRY : Mexico
RIVER : Yaqui
LOCATION OF CENTER OF RESERVOIR : 29.15N, 109.65W
LOCATION OF DAM : 28.90N, 109.62W
PROVINCE OR REGION : Sonora
DAM TYPE : Cupola arch
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply
NOTES ON DAM : Dam height of 123 m above ground; y-shaped reservoir
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 138. (m) above foundation
LENGTH OF DAM : 420. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 120.00 m
MAXIMUM VOLUME OF RESERVOIR : 3030. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 51.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Massive rhyolite, breccia, and conglomerate
SITE GEOLOGY : Volcanic
GEOLOGY REFERENCES : 106, 161A

## Emosson

DAM NAME : Emosson
RESERVOIR NAME : Lake Emosson or Lac de Barbarine
COUNTRY : Switzerland
RIVER : Barbarine
LOCATION OF CENTER OF RESERVOIR : 46.09N, 6.91E
LOCATION OF DAM : 46.08N, 6.92E
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1975
DATE OF START OF FILLING : May-1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N15W
STRUCTURAL HEIGHT OF DAM : 180. m
LENGTH OF DAM : 529. m
MAXIMUM DEPTH OF RESERVOIR : 170.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 170.00 m
MAXIMUM VOLUME OF RESERVOIR : 225. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.0 (km) km
NOTES ON REGIONAL GEOLOGY : On the periphery of the Mont Blanc granite intrusive within the Swiss Alps. Late Paleozoic gneiss and Jurassic flysch deposits.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Permian
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and reservoir underlain by metamorphic rock, principally Permian gneiss.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Permian
ORIENTATION OF STRUCTURAL GRAIN : SW
NOTES ON FAULTING : Faults of unreported age and orientation have been identified in the reservoir area. A major fault of unreported age crosses the reservoir near the area where the water depth is the greatest. The Martigny-Chur fault zone, considered by some investigators to be active with normal displacement, trends northeast downstream from the dam and reservoir.
DISTANCE TO CLOSEST KNOWN FAULT : 15.0 (km) km
DATE OF FIRST SUSPECTED RIS EVENT : Dec-1973
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Increase in level of microseismicity. Good spatial association with reservoir, as well as temporal correlation with initial impoundment and water level changes.
GENERAL NOTES : Data reliability is moderate. Pre-impoundment monitoring conducted; few additional data were obtained to verify that post-impoundment seismicity was reservoir induced.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 55, 56, 108, 405, 406

## Escales

DAM NAME : Escales
RESERVOIR NAME : Embalse de Escales
COUNTRY : Spain
RIVER : Noguera Ribagorzana
LOCATION OF CENTER OF RESERVOIR : 42.34N, 0.74E
PROVINCE OR REGION : Lerida/Huesca
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1955
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 113 m above ground
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 125. m
LENGTH OF DAM : 200. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 107.00 m
MAXIMUM VOLUME OF RESERVOIR : 158. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 9.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Shale and limestone
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 106, 468A

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Eucumbene .


DAM NAME : Eucumbene
RESERVOIR NAME : Lake Eucumbene
COUNTRY : Australia
RIVER : Eucumbene
LOCATION OF CENTER OF RESERVOIR : 36.08S,148.72E
LOCATION OF DAM : 36.13S,148.62E
PROVINCE OR REGION : New South Wales
DAM TYPE : Earth () fill
DATE DAM COMPLETED : May-1958
DATE OF START OF FILLING : 22-Jun-1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 116 m above ground; Reservoir is T-shaped.
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 116. (m) above foundation
MAXIMUM DEPTH OF RESERVOIR : 106.0 (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 106.00 m
MAXIMUM VOLUME OF RESERVOIR : 4761. m3x10E6
SURFACE AREA OF RESERVOIR : 145.00 km2
LONGEST DIMENSION OF RESERVOIR : 32.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Closely jointed siltstone and quartzite
SITE GEOLOGY : Metamorphic
NOTES ON FAULTING : The northeast-trending fault, approximately 35 km west of the reservoir, has Pleistocene or younger displacement
thrust toward the northwest. A northeast-trending southeastward thrust fault parallel to the Crackenback fault, less than 10 km from
the reservoir, has had recent seismicity (including the maximum event after impoundment).
DATE OF FIRST SUSPECTED RIS EVENT : 18-May-1959
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 5.0
DATE OF LARGEST SUSPECTED RIS EVENT : 18-May-1959
NOTES ON SEISMICITY BEFORE IMPOUNDMENT : Only one minor event recorded in 12 years of monitoring prior to impoundment.
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Increase in macroseismicity during initial impoundment, in close spatial association with
reservoir.  Additional macroseismicity associated with water level changes.
RIS CATEGORY : Accepted
TYPE OF  RIS : macro
GEOLOGY REFERENCES : 40,99,100,103,106,203,321,456,460
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**Fairfield**

DAM NAME : Fairfield
RESERVOIR NAME : Lake Monticello
COUNTRY : USA
LOCATION OF CENTER OF RESERVOIR : 34.34N, 81.32W
PROVINCE OR REGION : South Carolina
DAM TYPE : Earth
DATE OF START OF FILLING : Dec-1977
RATE OF INITIAL FILLING : 16.30 m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 0.25 years
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (), pumped storage facility
MAXIMUM DEPTH OF RESERVOIR : 49.0 (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 30.00 m
SURFACE AREA OF RESERVOIR : 28.00 km2
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
DATE OF FIRST SUSPECTED RIS EVENT : Dec-1977
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : 2.8
DATE OF LARGEST SUSPECTED RIS EVENT : Oct-1978
NOTES ON SEISMICITY BEFORE IMPOUNDMENT : Pre-impoundment micro monitoring from USGS station 3 miles away for 4 fears. Ambient level 1 event every 6 days.
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Late December micro activity picks up; maximum of 100 events in one day. Local 4-station network on-line in December 1977. Level of activity decreased March 1978. Largest events: M 2.7 Aug. 1978, M 2.8 Oct. 1978. Gradual decrease in seismic activity into early 1979.
GENERAL NOTES : Data obtained from Bob Wharton, South Carolina Electric and Power Company.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : Zoback, personal communication

Fengman (Fang-man)

DAM NAME : Fengman (Fang-man)
RESERVOIR NAME : Sung-hua Hu (Sungari Reservoir)
COUNTRY : China (PRC)
RIVER : Songhua Jiang (Sung-hua Chiang, Sungari)
LOCATION OF CENTER OF RESERVOIR : 43.44N,126.91E
LOCATION OF DAM : 43.76N,126.65E
PROVINCE OR REGION : Jilin (Kirin)
DAM TYPE : Gravity
DATE DAM COMPLETED : 1955
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
NOTES ON DAM : T-shaped reservoir with arms oriented SW and SE
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 91. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 81.90 m
MAXIMUM VOLUME OF RESERVOIR : 10778. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 95.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 108

## Flaming Gorge

DAM NAME : Flaming Gorge
RESERVOIR NAME : Flaming Gorge
COUNTRY : USA
RIVER : Green
LOCATION OF CENTER OF RESERVOIR : 41.25N,109.50W
LOCATION OF DAM : 40.80N,109.77W
PROVINCE OR REGION : Utah/Wyoming
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1964
DATE OF START OF FILLING : Nov-1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Reservoir extends west for 21 km, then north for 51 km
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 153. m
MAXIMUM DEPTH OF RESERVOIR : 139.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 139.00 m
MAXIMUM VOLUME OF RESERVOIR : 4674. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 51.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Quartzite and alluvium, 20 degrees upstream dip
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : PreCambrian
DEGREE OF DEFORMATION : Shallow dipping
GEOLOGY REFERENCES : 106,289,310

## Fontana

DAM NAME : Fontana

RESERVOIR NAME : Fontana Lake

COUNTRY : USA

RIVER : Little Tennessee

LOCATION OF CENTER OF RESERVOIR : 35.43N,83.63W

PROVINCE OR REGION : North Carolina

DAM TYPE : Concrete gravity

DATE DAM COMPLETED : 1944

EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower

NOTES ON DAM : Dam height of 140 m above ground

ORIENTATION OF RESERVOIR : S85E

STRUCTURAL HEIGHT OF DAM : 146. (m) above foundation

LENGTH OF DAM : 721. m

RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 128.00 m

MAXIMUM VOLUME OF RESERVOIR : 1782. m3x10E6

SURFACE AREA OF RESERVOIR : 51.00 km2

LONGEST DIMENSION OF RESERVOIR : 24.0 (km) km

NOTES ON REGIONAL GEOLOGY : Regional anticline in Great Smokey Formation (PreCambrian and Cambrian)

AGE OF REGIONAL GEOLOGY : Cambrian

TECTONIC PROVINCE : Appalachian Mountains

REGIONAL STRESS REGIME : Extensional

EVIDENCE FOR REGIONAL STRESS REGIME : tectonics

CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium

NOTES ON SITE GEOLOGY : Quartzite with thin phyllite, interbedded with phyllite with thin quartzite. Numerous fractures forming rhombic blocks. Dip of strata 15 to 75 degrees

SITE GEOLOGY : Metamorphic

GEOLOGY REFERENCES : 106,468A

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Fort Peck.


DAM NAME : Fort Peck
RESERVOIR NAME : Fort Peck Lake
COUNTRY : USA
RIVER : Missouri
LOCATION OF CENTER OF RESERVOIR : 47.75N,106.83W
LOCATION OF DAM : 47.87N,106.63W
PROVINCE OR REGION : Montana
DAM TYPE : Earth
DATE DAM COMPLETED : 1940
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (); multi-purpose
ORIENTATION OF RESERVOIR : S67W
STRUCTURAL HEIGHT OF DAM : 76. m
LENGTH OF DAM : 6409. m
MAXIMUM DEPTH OF RESERVOIR : 67.0 (m) (Corps of Engineers)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 67.00 m
MAXIMUM VOLUME OF RESERVOIR : 23930. m3x10E6
SURFACE AREA OF RESERVOIR : 1161.00 km2
LONGEST DIMENSION OF RESERVOIR : 150.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Shale
SITE GEOLOGY : Fine clastic
GEOLOGY REFERENCES : 106,289
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## Forte Buso

DAM NAME : Forte Buso
RESERVOIR NAME : Lago di Forte Buso
COUNTRY : Italy
RIVER : Travignolo
LOCATION OF CENTER OF RESERVOIR : 46.30N,11.74E
PROVINCE OR REGION : Trento
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1952
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 105 m above ground
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 110. m
LENGTH OF DAM : 421. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 92.00 m
MAXIMUM VOLUME OF RESERVOIR : 33. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.0 (km) km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Porphyry
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,289

Frera

DAM NAME : Frera
RESERVOIR NAME : Lago Belviso
COUNTRY : Italy
RIVER : Belviso
LOCATION OF CENTER OF RESERVOIR : 46.09N, 10.13E
PROVINCE OR REGION : Sondrio
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1959
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 130 m above ground
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 138. m
LENGTH OF DAM : 315. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 120.00 m
MAXIMUM VOLUME OF RESERVOIR : 50. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 2.6 (km) km
NOTES ON REGIONAL GEOLOGY : Crystalline rocks of the Insubrian series. Insubrian fault system located 9 km north
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Quartz phyllite
SITE GEOLOGY : Metamorphic
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : E to W
MAXIMUM LENGTH OF FAULTS : 110.00 (km) km for thrust; 250+.km for Insubrian Line
DOMINANT SIDE UP : N (); north
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Underthrust block of Insubrian Line; upthrown block () of thrust
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; unnamed fault crosses south end of reservoir
GEOLOGY REFERENCES : 106, 440A, 440B

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Furnas


DAM NAME : Furnas
RESERVOIR NAME : Furnas
COUNTRY : Brazil
RIVER : Grande
LOCATION OF CENTER OF RESERVOIR : 20.75S,46.00W
LOCATION OF DAM : 20.64S,46.36W
PROVINCE OR REGION : Minas Gerais
DAM TYPE : Earth () and rock fill
DATE DAM COMPLETED : 1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 123. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 110.70 m
MAXIMUM VOLUME OF RESERVOIR : 20200. m3x10E6
SURFACE AREA OF RESERVOIR : 1606.00 km2
LONGEST DIMENSION OF RESERVOIR : 140.0 km
NOTES ON REGIONAL GEOLOGY : Algonquian rocks of Minas and Itacolomi Series schists and quartzites.  Regional fold axes N50-60W.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Precambrian
TECTONIC PROVINCE : Brazil shield
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Quartzite and schist in dam foundation.  Main regional fault crosses river just upstream from dam site.
Schist and quartzite highly fractured in vicinity of fault.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Precambrian
AZIMUTH OF PREDOMINANT FAULTING : N55W
DIP OF PREDOMINANT FAULTING : 85NE at dam
MAXIMUM LENGTH OF FAULTS : 20.00 (km) km
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Crosses through arm of reservoir just upstream of dam.
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; crosses reservoir 2 km upstream from dam
GEOLOGY REFERENCES : 106,152,443
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Garrison

DAM NAME : Garrison
RESERVOIR NAME : Lake Sakakawea
COUNTRY : USA
RIVER : Missouri
LOCATION OF CENTER OF RESERVOIR : 47.83N, 102.33W
LOCATION OF DAM : 47.37N, 101.42W
PROVINCE OR REGION : North Dakota
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (), multi-purpose
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 64. m
LENGTH OF DAM : 3444. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 60.80 m
MAXIMUM VOLUME OF RESERVOIR : 30221. m3x10E6
SURFACE AREA OF RESERVOIR : 1849.00 km2
LONGEST DIMENSION OF RESERVOIR : 207.0 km
NOTES ON REGIONAL GEOLOGY : Missouri Plateau. Pleistocene alluvium up to 60 m depth in Missouri River flood plain. Paleocene Fort Union Formation, 300 m thick clay, sand, and lignite.
REGIONAL GEOLOGY : Fine clastic
AGE OF REGIONAL GEOLOGY : Paleocene
TECTONIC PROVINCE : Great Plains -- Missouri Plateau -- Continental interior
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Tertiary thin-bedded sandstone and clay of Fort Union Formation on abutments. Floodplain includes alluvium of 30 m to 60 m thickness
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Paleocene
GEOLOGY REFERENCES : 32, 106, 289

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Gebidem


DAM NAME : Gebidem
COUNTRY : Switzerland
RIVER : Massa
LOCATION OF CENTER OF RESERVOIR : 46.37N,7.99E
PROVINCE OR REGION : Wallis
DAM TYPE : Concrete arch () dome
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 120. (m) above lowest foundation
LENGTH OF DAM : 325. m
MAXIMUM DEPTH OF RESERVOIR : 104.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 104.00 m
MAXIMUM VOLUME OF RESERVOIR : 10. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 1.4 (km) km
NOTES ON REGIONAL GEOLOGY : Autochthonous massif
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : High strength gneiss, widely-spaced nearly vertical foliation oriented oblique to the Massa stream.  Three
joint systems:  two vertical, one oblique with 10 to 30 degree dip
SITE GEOLOGY : Metamorphic
MAXIMUM LENGTH OF FAULTS : 80.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km
GEOLOGY REFERENCES : 106,176,459
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Gepatsch

DAM NAME : Gepatsch
RESERVOIR NAME : Gepatsch-See
COUNTRY : Austria
RIVER : Faggenbach
LOCATION OF CENTER OF RESERVOIR : 46.95N, 10.76E
LOCATION OF DAM : 46.97N, 10.76E
PROVINCE OR REGION : Tyrol
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 110 m above ground
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 153. m
LENGTH OF DAM : 630. m
MAXIMUM DEPTH OF RESERVOIR : 110.0 (m) m (calculated from drawing)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 110.00 m
MAXIMUM VOLUME OF RESERVOIR : 140. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 5.4 (km) km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Gneiss overlain by bouldery clay and glacial drift
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106, 289

Ghirni

DAM NAME : Ghirni
COUNTRY : India
RIVER : Ghirni
LOCATION OF DAM : 18.37N, 76.83E
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1966
STRUCTURAL HEIGHT OF DAM : 16. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 15.20 m
MAXIMUM VOLUME OF RESERVOIR : 3. m3x10E6
NOTES ON REGIONAL GEOLOGY : Margin of the Peninsular Shield of India.
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Correlation between impoundment and seismicity: isolated seismic activity subsequent to impoundment.
GENERAL NOTES : Insufficient data available to evaluate induced seismicity. No macro-earthquakes reported by ISC in dam vicinity.
RIS CATEGORY : Questionable ().
GEOLOGY REFERENCES : 106, 192, 203

Gigerwald

DAM NAME : Gigerwald
COUNTRY : Switzerland
RIVER : Tamina
PROVINCE OR REGION : St. Gallen
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1976
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 147. (m) above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 129.00 m
MAXIMUM VOLUME OF RESERVOIR : 33. m3x10E6
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 107,108

Glen Canyon

DAM NAME : Glen Canyon
RESERVOIR NAME : Lake Powell
COUNTRY : USA
RIVER : Colorado
LOCATION OF CENTER OF RESERVOIR : 37.07N, 111.22W
LOCATION OF DAM : 36.95N, 111.48W
PROVINCE OR REGION : Arizona/Utah
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1964
DATE OF START OF FILLING : Began May-1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (); multi-purpose
ORIENTATION OF RESERVOIR : N55E
STRUCTURAL HEIGHT OF DAM : 216. m
MAXIMUM DEPTH OF RESERVOIR : 178.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 178.00 m
MAXIMUM VOLUME OF RESERVOIR : 33305. m3x10E6
TECTONIC PROVINCE : Colorado Plateau
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and portions of reservoir underlain by Navajo sandstone of Jurassic age.
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Jurassic
GEOLOGY REFERENCES : 84, 92, 106, 310

Gokcekaya

DAM NAME : Gokcekaya
COUNTRY : Turkey
RIVER : Sakarya
LOCATION OF CENTER OF RESERVOIR : 40.05N,31.32E
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 160. (m) above foundation
LENGTH OF DAM : 495. m
MAXIMUM DEPTH OF RESERVOIR : 115.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 115.00 m
MAXIMUM VOLUME OF RESERVOIR : 910. m3x10E6
SURFACE AREA OF RESERVOIR : 22.30 km2
LONGEST DIMENSION OF RESERVOIR : 50.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Metamorphic greenstone and greenschist. Serpentine mass bordered by talc immediately upstream of dam. Inactive fault zone on left abutment, another fault in top half right abutment.
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 76A,107,108,181,348A

## Gordon

DAM NAME : Gordon
RESERVOIR NAME : Lake Gordonr
COUNTRY : Australia
RIVER : Hobart
LOCATION OF CENTER OF RESERVOIR : 42.70S,146.10E
PROVINCE OR REGION : Tasmania
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1974
DATE OF START OF FILLING : Inundation began 1972
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Reservoir adjoins Lake Pedder
STRUCTURAL HEIGHT OF DAM : 140. m
MAXIMUM DEPTH OF RESERVOIR : 128.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 128.00 m
MAXIMUM VOLUME OF RESERVOIR : 11728. m3x10E6
SURFACE AREA OF RESERVOIR : 272.00 km2
NOTES ON REGIONAL GEOLOGY : Low-grade pre-Cambrian metamorphics. Regional geology includes pre-Cambriam or Cambrian shale and sandstone, unmetamorphosed, and some limestone.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Precambrian
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Reservoir, low-grade Precambrian metamorphics including quartzite, phyllite and schist. Dam site structure is broad antiform with minor (1m-10m) folds on flanks. Antiform plunges gently south. Pre-Cambrian quartzite and schist in foundation, jointed. Major gullies reflect fault zones or major joints.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Precambrian
GEOLOGY REFERENCES : 24,107,108,299

Goschener Alp   (Goeschener Alp)

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DAM NAME : Goschener Alp   (Goeschener Alp)
RESERVOIR NAME : Goschener Alp
COUNTRY : Switzerland
RIVER : Goeschenerreuss
LOCATION OF CENTER OF RESERVOIR : 46.79N,8.50E
LOCATION OF DAM : 46.79N,8.51E
PROVINCE OR REGION : Uri
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 155. (m) above lowest foundation
LENGTH OF DAM : 540. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 139.50 m
MAXIMUM VOLUME OF RESERVOIR : 75. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 1.6 (km) km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Granite overlain by alluvial deposits
SITE GEOLOGY : Batholithic
DISTANCE TO CLOSEST KNOWN FAULT : 7.0 (km) km
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Historic events of MSK VIII and IX are located within 10 km of the reservoir; 4 events from
1001 to 1976.
GEOLOGY REFERENCES : 106,289
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Grancarevo

DAM NAME : Grancarevo
RESERVOIR NAME : Bileca
COUNTRY : Yugoslavia
RIVER : Trebisnjica
LOCATION OF CENTER OF RESERVOIR : 42.75N,18.48E
LOCATION OF DAM : 42.70N,18.40E
PROVINCE OR REGION : Bosna Hercegov
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1967
DATE OF START OF FILLING : Nov-1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 107 m above ground, inverted L-shaped reservoir.
STRUCTURAL HEIGHT OF DAM : 123. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 105.00 m
MAXIMUM VOLUME OF RESERVOIR : 1280. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 17.0 km
NOTES ON REGIONAL GEOLOGY : Dinaride Mountains undergoing uplift relative to Adriatic coastline. Bedrock fissured, faulted, and jointed, consisting principally of Mesozoic limestone.
REGIONAL GEOLOGY : Carbonate
AGE OF REGIONAL GEOLOGY : Mesozoic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Karstified, faulted, fissured, and jointed Mesozoic limestone.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Mesozoic
TYPE OF PERMEABILITY : Cavernous
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : Dec-1967
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Microearthquake activity increased in frequency to 30 times that of pre-impoundment activity within an approximate 20 km radius of the dam and reservoir. No increase in macroseismicity was observed.80 percent of events that occurred in the 3 years subsequent to reservoir impoundment were within 5 km of the dam and reservoir. Focal depths were not obtained.
GENERAL NOTES : Data reliability is good. Pre-impoundment micro- earthquake activity documented to be less than post-impoundment activity. No change in macroseismicity.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 64,106,391,418

Grand Coulee

DAM NAME : Grand Coulee
RESERVOIR NAME : Franklin Delano Roosevelt Lake
COUNTRY : USA
RIVER : Columbia
LOCATION OF CENTER OF RESERVOIR : 48.33N,118.17W
LOCATION OF DAM : 47.95N,118.98W
PROVINCE OR REGION : Washington
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1942
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Reservoir extends 79 km to east as well as 100 km to north
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 168. m
LENGTH OF DAM : 1272. m
MAXIMUM DEPTH OF RESERVOIR : 116.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 116.00 m
MAXIMUM VOLUME OF RESERVOIR : 11790. m3x10E6
SURFACE AREA OF RESERVOIR : 393.00 km2
LONGEST DIMENSION OF RESERVOIR : 110.0 km
NOTES ON REGIONAL GEOLOGY : Plio-Pleistocene basalt folded/faulted along W-NW structural axes.
REGIONAL GEOLOGY : Volcanic
AGE OF REGIONAL GEOLOGY : Pliocene
TECTONIC PROVINCE : Columbia Plateau
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : Tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : Low
NOTES ON SITE GEOLOGY : K to Tertiary granite at dam; 80 km upstream: granite in river, basalt capping hills.
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Pliocene
GEOLOGY REFERENCES : 106,434A

Grand Dixence

DAM NAME : Grand Dixence
RESERVOIR NAME : Lac des Dix
COUNTRY : Switzerland
RIVER : Dixence
LOCATION OF CENTER OF RESERVOIR : 46.06N,7.40E
LOCATION OF DAM : 46.08N,7.40E
PROVINCE OR REGION : Valais
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 285. m
LENGTH OF DAM : 695. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 255.00 m
MAXIMUM VOLUME OF RESERVOIR : 400. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 5.4 km
NOTES ON REGIONAL GEOLOGY : Mesozoic schist. Thrust faults toward northwest in Pennine Nappe pass through reservoir and dam.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Jurassic-Cretaceous schist
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Jurassic
ORIENTATION OF STRUCTURAL GRAIN : NE
DEGREE OF DEFORMATION : strongly deformed
NOTES ON FAULTING : Major intra-nappe thrust fault passes through or adjacent to dam and corner of reservoir.
PREDOMINANT FAULT TYPE : thrust
AZIMUTH OF PREDOMINANT FAULTING : NE
DOMINANT SIDE UP : SE (), southeast
LOCATION OF RESERVOIR IN RELATION TO FAULTS : upthrown block
DISTANCE TO CLOSEST KNOWN FAULT : 26.0 (km) km
NOTES ON SEISMICITY BEFORE IMPOUNDMENT : Historical earthquakes between 1755 and 1976 within 8 km of reservoir, MSK VI andVII.
GEOLOGY REFERENCES : 106,434

DAM NAME : Grandval
COUNTRY : France
RIVER : Truyere
LOCATION OF CENTER OF RESERVOIR : 44.97N,3.10E
LOCATION OF DAM : 44.90N,3.07E
DAM TYPE : Concrete multiple arch
DATE DAM COMPLETED : 1959
NOTES ON HISTORY OF IMPOUNDMENT : Initial filling of the lake took 6 months. The lake was completely dscharged in March 1962 and refilled by August-September 1963.
DATE OF START OF FILLING : 15-Sep-1959
RATE OF INITIAL FILLING : 13.00 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 0.50 (years) year
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : V-shaped reservoir; principal arm oriented NE, other arm oriented S. Dam height 80 m above ground.
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 88. (m) above found.
LENGTH OF DAM : 400. m
MAXIMUM DEPTH OF RESERVOIR : 78.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 78.00 m
MAXIMUM VOLUME OF RESERVOIR : 292. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 18.0 km
NOTES ON REGIONAL GEOLOGY : Paleozoic gneiss and granite overlain by Cenozoic volcanics
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Paleozoic
TECTONIC PROVINCE : Massif Central
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Tectonically deformed Paleozoic mica schist; deformation includes folding, fracturing and faulting.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Paleozoic
AZIMUTH OF PREDOMINANT FAULTING : NE
MAXIMUM LENGTH OF FAULTS : 4.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : 3.6 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Post emplacement of granite
DATE OF FIRST SUSPECTED RIS EVENT : 31-Dec-1961
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : MM V
DATE OF LARGEST SUSPECTED RIS EVENT : 5-Aug-1963
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Microseismicity associated with initial filling. After reservoir emptied and refilled, increase in macroseismicity clearly associated with refilling and water level fluctuations.
GENERAL NOTES : Data reliability is low to moderate. Few data were obtained. Tectonically disturbed area.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 43,64,331,393

Green Peter

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DAM NAME : Green Peter
RESERVOIR NAME : Green Peter
COUNTRY : USA
RIVER : Middle Santiam
LOCATION OF CENTER OF RESERVOIR : 44.47N,122.50W
PROVINCE OR REGION : Oregon
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Flood control () is first use listed
NOTES ON DAM : Dam height of 104 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 111. (m) above foundation
LENGTH OF DAM : 421. m
MAXIMUM DEPTH OF RESERVOIR : 97.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 97.00 m
MAXIMUM VOLUME OF RESERVOIR : 530. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 14.5 (km) km
NOTES ON REGIONAL GEOLOGY : Tertiary massive lava flows with thin interbedded volcanic or volcanic-derived tuffs, intruded by
younger basaltic dikes or sheets
REGIONAL GEOLOGY : Volcanic
AGE OF REGIONAL GEOLOGY : Tertiary
TECTONIC PROVINCE : Cascades
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Several shear zones in dam area formed during uplift of Cascades; interbedded basalts and tuffs, shallow dip
toward left abutment.
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Tertiary
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N to NW () trending
MAXIMUM LENGTH OF FAULTS : 10.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : Fault about 8.0 (km) km to east; another 20 km to west
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Fault 8 km to east is pre-late Tertiary; fault 20 km to west is late
Tertiary
GEOLOGY REFERENCES : 106,112,187A,224,337
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Guri


DAM NAME : Guri
COUNTRY : Venezuela
RIVER : Caroni
LOCATION OF CENTER OF RESERVOIR : 7.53N,62.87W
LOCATION OF DAM : 7.77N,62.98W
PROVINCE OR REGION : Bolivar
DAM TYPE : Rock () fill buttress with concrete gravity spillway section
DATE DAM COMPLETED : 1968
NOTES ON DAM : Dam expansion under construction.  Upon completion in 1985, expected to be 162 m high, 9404 in length, with reservoir
139000E06 cubic m.
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 106. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 95.40 m
MAXIMUM VOLUME OF RESERVOIR : 17700. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 113.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 106,108
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## Hatanagi No. 1

DAM NAME : Hatanagi No. 1
COUNTRY : Japan
RIVER : Oi
LOCATION OF CENTER OF RESERVOIR : 35.31N,138.18E
LOCATION OF DAM : 35.30N,138.20E
PROVINCE OR REGION : Shizuoka
DAM TYPE : Hollow gravity
DATE DAM COMPLETED : 1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (); pump-storage plant
NOTES ON DAM : Dam height of 105 m above ground
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 125. m
LENGTH OF DAM : 269. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 107.00 m
MAXIMUM VOLUME OF RESERVOIR : 107. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 5.5 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Shale
SITE GEOLOGY : Fine clastic
GEOLOGY REFERENCES : 106,289

**Hendrik Verwoerd**

DAM NAME : Hendrik Verwoerd
RESERVOIR NAME : Hendrik Verwoerd
COUNTRY : South Africa
RIVER : Orange
LOCATION OF CENTER OF RESERVOIR : 30.63S, 25.78E
LOCATION OF DAM : 30.63S, 25.50E
DAM TYPE : Concrete double arch
DATE DAM COMPLETED : 1970
DATE OF START OF FILLING : Sep-1970
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : N75W
STRUCTURAL HEIGHT OF DAM : 66. m
LENGTH OF DAM : 600. m
MAXIMUM DEPTH OF RESERVOIR : 55.0 (m) (measured from level data)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 55.00 m
MAXIMUM VOLUME OF RESERVOIR : 5000. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 60.0 (km) km
NOTES ON REGIONAL GEOLOGY : Near the center of a basin within a relatively stable shield area. Upper Paleozoic to lower Mesozoic Karoo System is underlain by Precambrian cavernous dolomite, which is underlain by the Precambrian Witwaterstrand quartzite.
REGIONAL GEOLOGY : Fine clastic
AGE OF REGIONAL GEOLOGY : lower Mesozoic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Horizontal upper Paleozoic to lower Mesozoic Karoo System of mudstone, sandstone and shale intruded by dolerite dikes and sheets. Probably underlain by cavernous Precambrian dolomite.
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : lower Mesozoic
NOTES ON HYDROLOGY : Probably low surficial permeability in dense, competent, flatlying sedimentary units. Underlying cavernous dolomite is an aquifer. Groundwater probably perched except where fractures or minor faults may provide hydraulic continuity with the aquifer.
PERMEABILITY OF ROCKS : low (); 1 percent to 2 percent porosity in Hiroo.
TYPE OF PERMEABILITY : impervious () in Hiroo, cavernous in dolomite
DATE OF FIRST SUSPECTED RIS EVENT : Feb-1971 () Magnitude less than 2
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Microseismicity related to initial impoundment, with increase as maximum water level reached. Possible relationship to early stages of fluctuations, but after about 1.5 years seismicity decreased to near pre-impoundment levels.
GENERAL NOTES : Data reliability is moderate to good. Pre-impoundment data were obtained; epicenters were located beneath the reservoir at a shallow depth.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 107, 183, 203, 418

Hitotsuse

DAM NAME : Hitotsuse
COUNTRY : Japan
RIVER : Hitotsuse
LOCATION OF CENTER OF RESERVOIR : 32.21N,131.13E
PROVINCE OR REGION : Miyazaki
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : 120 m above ground
STRUCTURAL HEIGHT OF DAM : 130. m
LENGTH OF DAM : 416. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.00 m
MAXIMUM VOLUME OF RESERVOIR : 261. m3x10E6
SURFACE AREA OF RESERVOIR : 8.86 km2
LONGEST DIMENSION OF RESERVOIR : 22.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Mesozoic sandstone and shale
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Mesozoic
GEOLOGY REFERENCES : 106,316,326

Hongrin Nord

DAM NAME : Hongrin Nord
COUNTRY : Switzerland
RIVER : Hongrin
LOCATION OF CENTER OF RESERVOIR : 46.39N, 7.05E
LOCATION OF DAM : 46.39N, 7.04E
PROVINCE OR REGION : Vaud
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 125. (m) above lowest foundation
LENGTH OF DAM : 325. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 107.00 m
MAXIMUM VOLUME OF RESERVOIR : 53. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 3.8 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Limestone dipping 40 to 50 degrees upstream
SITE GEOLOGY : Carbonate
MAXIMUM LENGTH OF FAULTS : 2.50 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : less than 1.0 (km) km
GEOLOGY REFERENCES : 106, 176

DAM NAME : Hoover (Boulder)
RESERVOIR NAME : Lake Mead
COUNTRY : USA
RIVER : Colorado
LOCATION OF CENTER OF RESERVOIR : 36.13N, 114.43W
LOCATION OF DAM : 36.02N, 114.75W
PROVINCE OR REGION : Arizona and Nevada
DAM TYPE : Concrete arch ()-gravity
DATE DAM COMPLETED : 1936
DATE OF START OF FILLING : May-1935
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () is first use listed.
NOTES ON DAM : 176 m above ground; y-shaped reservoir
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 221. (m) above foundation
LENGTH OF DAM : 379. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 191.00 m
MAXIMUM VOLUME OF RESERVOIR : 36703. m3x10E6
SURFACE AREA OF RESERVOIR : 593.00 (km2) (1)
LONGEST DIMENSION OF RESERVOIR : 118.0 km
NOTES ON REGIONAL GEOLOGY : Paleozoic/Mesozoic sediments overlain by Tertiary volcanics, sandstone, conglomerate, salt, gypsum. Late Tertiary extension and block faulting.
REGIONAL GEOLOGY : Volcanic
AGE OF REGIONAL GEOLOGY : Tertiary
TECTONIC PROVINCE : Basin and Range
REGIONAL STRESS REGIME : E-W Extensional () with shear component
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism ()s
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Tertiary basalt and andesite with tuft, rhyolitic glass, and breccia at dam reservoir: Muddy Creek Fm. (congl., sandstone, clay, basalt, salt, gypsum; late Tertiary); Tertiary quartz monzonite and granodiorite; Precambrian metamorphic and granite.
SITE GEOLOGY : Fine clastic () (Muddy Creek Fm.)
AGE OF SITE GEOLOGY : Tertiary
NOTES ON FAULTING : Faults in Lake Mead area are predominantly normal; however, a significant right-lateral component may be present on some faults.
PREDOMINANT FAULT TYPE : Normal (); some right-lateral
AZIMUTH OF PREDOMINANT FAULTING : N to NW (); 60 deg
LOCATION OF RESERVOIR IN RELATION TO FAULTS : 4 major faults in reservoir
NAME OF CLOSEST KNOWN FAULT : Mead Slope fault
DISTANCE TO CLOSEST KNOWN FAULT : in reservoir, 0.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary, possibly
ARE LOCAL FAULTS ACTIVE? : Yes
SEISMICITY ASSOCIATED WITH FAULTS IN LOCAL AREA? : Yes
NOTES ON HYDROLOGY : Eastern basin: low (evaporites, fine-grained clastics); western basin higher.
PERMEABILITY OF ROCKS : low
DEGREE OF TOPOGRAPHIC RELIEF : high (); varies, such that in some areas relief is low to moderate
DATE OF FIRST SUSPECTED RIS EVENT : Sep-1936
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 5 (NOAA)
DATE OF LARGEST SUSPECTED RIS EVENT : 10-Mar-1940
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Good correlation during initial years after reservoir impoundment through approximately 1949 between seismicity and water levels. Correlation was poor in subsequent years. The initial good correlation showed seismic frequency increasing and decreasing virtually simultaneously with seasonal increases and decreases, respectively, in water level.

Most events occurred within 25 km of the reservoir. 1940 to 1944 events concentrated along faults along the southeast shore of reservoir. 1972 to 1973 events ourred in scattered clusters with major concentration at intersection of three faults in reservoir. Focal depths of 1936 to 1944 events were 9 km. 1972 events had focal depths of 1.5 to 6 km.

GENERAL NOTES : Data reliability is good. An increase in seismicity subsequent to reservoir impoundment occurred. Temporal and spatial relationships of seismicity to the reservoir impoundment exist.

RIS CATEGORY : Accepted

TYPE OF RIS : macro and micro

GEOLOGY REFERENCES : 21, 22, 23, 64, 82, 83, 84, 85, 106, 203, 273, 282, 331, 380, 386, 388, 393, 473

Hungry Horse

DAM NAME : Hungry Horse
RESERVOIR NAME : Hungry Horse
COUNTRY : USA
RIVER : South Fork Flathead
LOCATION OF CENTER OF RESERVOIR : 48.15N,113.83W
LOCATION OF DAM : 48.23N,114.07W
PROVINCE OR REGION : Montana
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1953
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; first listing is Irrigation
NOTES ON DAM : Dam height of 158 m above ground
ORIENTATION OF RESERVOIR : SE
STRUCTURAL HEIGHT OF DAM : 172. m
LENGTH OF DAM : 645. m
MAXIMUM DEPTH OF RESERVOIR : 159.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 159.00 m
MAXIMUM VOLUME OF RESERVOIR : 4278. m3x10E6
SURFACE AREA OF RESERVOIR : 113.00 km2
LONGEST DIMENSION OF RESERVOIR : 24.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Siyeh limestone-bedded, impervious due to impermeabilities; one major, several minor shear zones, 1 major bedding plane
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 106,148,289

Idikki

DAM NAME : Idikki
RESERVOIR NAME : Puayar Lake
COUNTRY : India
RIVER : Periyar
LOCATION OF CENTER OF RESERVOIR : 9.53N, 77.21E
LOCATION OF DAM : 9.53N, 77.15E
PROVINCE OR REGION : Kerala
DAM TYPE : Multi-arch
DATE DAM COMPLETED : 1975
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (); reservoir fills during rainy season, is emptied during dry season to provide hydropower
NOTES ON DAM : Two principal dams, Idikki and Cheruthoni, impound Puayar Lake. Idikki is higher dam.
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 169. m
LENGTH OF DAM : 355. m
MAXIMUM DEPTH OF RESERVOIR : 166.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 166.00 m
MAXIMUM VOLUME OF RESERVOIR : 1996. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 13.0 km
NOTES ON REGIONAL GEOLOGY : Pre-Cambrian gneiss intruded by pre-Cambrian granite, diorite, and charnockite; part of Indian Shield.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Pre-Cambrian
TECTONIC PROVINCE : Indian Shield
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam site consists of charnockite alternating with gneiss with near-vertical foliation.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : pre-Cambrian
NOTES ON FAULTING : Fault through auxiliary dam foundation; type and age not obtained
GEOLOGY REFERENCES : 106, 298, 381, 408A

## Ikehara

DAM NAME : Ikehara
COUNTRY : Japan
RIVER : Kitayama
PROVINCE OR REGION : Nara
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 106 m above ground
STRUCTURAL HEIGHT OF DAM : 111. m
LENGTH OF DAM : 460. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 93.00 m
MAXIMUM VOLUME OF RESERVOIR : 338. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 106

Ilha Solteira

DAM NAME : Ilha Solteira
COUNTRY : Brazil
RIVER : Parana
LOCATION OF CENTER OF RESERVOIR : 20.20S,51.06W
LOCATION OF DAM : 20.35S,51.27W
PROVINCE OR REGION : Sao Paulo/Mato Grasso
DAM TYPE : Earth () and rockfill
DATE DAM COMPLETED : 1973
DATE OF START OF FILLING : Impoundment commenced in Mar-1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 78. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 74.10 m
MAXIMUM VOLUME OF RESERVOIR : 21200. m3x10E6
SURFACE AREA OF RESERVOIR : 1230.00 km2
LONGEST DIMENSION OF RESERVOIR : 130.0 km
NOTES ON REGIONAL GEOLOGY : Basalts of upper Parana basin: successive thick lava flows up to 50 m, with intercalated soft sandstone.
REGIONAL GEOLOGY : Volcanic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Dam: Basalt underlain by breccia and another basalt flow.
SITE GEOLOGY : Volcanic
GEOLOGY REFERENCES : 71,107,108,453

Itezhitezhi

DAM NAME : Itezhitezhi
RESERVOIR NAME : Itezhitezhi
COUNTRY : Zambia
RIVER : Kafue
LOCATION OF CENTER OF RESERVOIR : 15.79S, 26.07E
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1978
DATE OF START OF FILLING : May-1976
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 65. (m) m
MAXIMUM DEPTH OF RESERVOIR : 62.0 (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 62.00 m
MAXIMUM VOLUME OF RESERVOIR : 5000. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 45.0 (km) km
REGIONAL GEOLOGY : Batholithic
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Site located in graben with down-dropped block of Karoo series Mesozoic mudstone overlying granite of unspecified age
SITE GEOLOGY : Batholithic
PREDOMINANT FAULT TYPE : Normal
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; through abutments and reservoir
DATE OF FIRST SUSPECTED RIS EVENT : May-1978
NOTES ON SEISMICITY BEFORE IMPOUNDMENT : Area of high level macroseismicity close to reservoir. This includes magnitudes 5.8 m (ISC) within 16 km of center of reservoir in 1968, eight years prior to filling.
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Felt earthquakes probably near reservoir associated with refilling one year after initial filling and emptying of reservoir.
GENERAL NOTES : No data were obtained
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 143; Iernelius, written communication

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Iwaya

DAM NAME : Iwaya
COUNTRY : Japan
RIVER : Mase
LOCATION OF CENTER OF RESERVOIR : 35.72N,137.12E
PROVINCE OR REGION : Gifu
DAM TYPE : Earth () and rockfill
DATE DAM COMPLETED : 1976
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
STRUCTURAL HEIGHT OF DAM : 128. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 115.20 m
MAXIMUM VOLUME OF RESERVOIR : 174. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Quartz porphyry, locally fractured.  Two faults found in core trench
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 108,319
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Iznajar

DAM NAME : Iznajar
RESERVOIR NAME : Embalse de Iznajar
COUNTRY : Spain
RIVER : Genil
LOCATION OF CENTER OF RESERVOIR : 37.24N,4.27W
LOCATION OF DAM : 37.27N,4.39W
PROVINCE OR REGION : Granada
DAM TYPE : Gravity
DATE DAM COMPLETED : 1969
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : S70E
STRUCTURAL HEIGHT OF DAM : 120. (m) above lowest foundation
MAXIMUM DEPTH OF RESERVOIR : 105.0 (m) m (calculated from drawing)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 105.00 m
MAXIMUM VOLUME OF RESERVOIR : 980. m3x10E6
SURFACE AREA OF RESERVOIR : 26.64 km2
LONGEST DIMENSION OF RESERVOIR : 38.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Jurassic limestone in right abutment faulted against Jurassic marlish clays; overlain by disrupted marlish clays overlain by Miocene arenaceous marl. Limestone fractured, intense local mylonitization
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Jurassic
GEOLOGY REFERENCES : 66,104A,107

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Jocassee


DAM NAME : Jocassee
RESERVOIR NAME : Lake Jocassee
COUNTRY : USA
RIVER : Keowee
LOCATION OF CENTER OF RESERVOIR : 34.98N,82.94W
LOCATION OF DAM : 34.97N,82.92W
PROVINCE OR REGION : South Carolina
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1973
DATE OF START OF FILLING : Apr-1971
RATE OF INITIAL FILLING : 4.00 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 3.00 (years) years
MAXIMUM RATE OF FILLING : 10.00 (m/month) m/month in April-May 1971
MAXIMUM RATE OF DRAWDOWM : 12.00 (m/month) m/month in July 1973.
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 133. (m) above lowest foundation
MAXIMUM DEPTH OF RESERVOIR : 107.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 107.00 m
MAXIMUM VOLUME OF RESERVOIR : 1431. m3x10E6
SURFACE AREA OF RESERVOIR : 30.00 (km2) km
LONGEST DIMENSION OF RESERVOIR : 18.0 km
NOTES ON REGIONAL GEOLOGY : Pre-Cambrian to early Paleozoic metamorphics including gneiss, schist, amphibolite, all highly deformed
and intruded by granitics during Paleozoic and possibly Mesozoic tectonic activity. Paleozoic stress regime was tensional, producin
regional thrust faults. Modern stress regime is tensional.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Paleozoic
TECTONIC PROVINCE : Piedmont
REGIONAL STRESS REGIME : Extensional () (NW-SE)
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Dam: Paleozoic Henderson Gneiss structurally overlying phyllite, mylonite, amphibolite, quartzite, and
carbonate of pre-Cambrian to Early Paleozoic Brevard Zone and Poor Mtn. Series.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Paleozoic
DEGREE OF DEFORMATION : strongly deformed
NOTES ON FAULTING : Individual faults vary in strike from N7E to N50E, N20W to N40W. Main Brevard zone is N35E.
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : N35E
DIP OF PREDOMINANT FAULTING : 20E to 55E dip
DOMINANT SIDE UP : SE (); southeast
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Brevard Zone through western area of reservoir, 3 faults
NAME OF CLOSEST KNOWN FAULT : Brevard Zone
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; in reservoir
DATE OF FIRST SUSPECTED RIS EVENT : 13-Jul-1971
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 3.2 (NOAA)
DATE OF LARGEST SUSPECTED RIS EVENT : 25-Nov-1975
NOTES ON SEISMICITY AFTER IMPOUNDMENT : First felt event subsequent to impoundment occurred 17 months after maximum water level was
attained. No apparent correlation was observed between variation of microearthquake frequency and water level during monitoring
period because the water level generally varied less than 10 feet.
GENERAL NOTES : Data reliability is moderate to low. Little pre-impoundment data were obtained. No temporal correlation of
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seismicity with variations in reservoir level. Spatial relationship of seismicity with reservoir exists.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 108, 134, 155, 156, 435

Kainji

DAM NAME : Kainji
RESERVOIR NAME : Kainji Lake
COUNTRY : Nigeria
RIVER : Niger
LOCATION OF CENTER OF RESERVOIR : 10.19N,4.54E
LOCATION OF DAM : 9.83N,4.58E
PROVINCE OR REGION : Northwestern
DAM TYPE : Rock () fill buttress with gravity dam spillway section
DATE DAM COMPLETED : 1969
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : 10 m each year on the average; Hydropower
STRUCTURAL HEIGHT OF DAM : 78. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 74.39 m
MAXIMUM VOLUME OF RESERVOIR : 15062. m3x10E6
SURFACE AREA OF RESERVOIR : 1240.00 km2
LONGEST DIMENSION OF RESERVOIR : 135.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Granite, gneiss, and schist in bedrock area. 60 m or more of alluvial sands in channel above dam site. Inactive faults in dam foundation.
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 107,142,144

## Kakhovka

DAM NAME : Kakhovka
RESERVOIR NAME : Kakhovskoye Vdkhr.
COUNTRY : USSR
LOCATION OF CENTER OF RESERVOIR : 47.42N, 34.17E
LOCATION OF DAM : 46.77N, 33.34E
PROVINCE OR REGION : Ukraine
DAM TYPE : Earth () buttress with concrete gravity spillway section.
DATE DAM COMPLETED : 1955
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 37. m
LENGTH OF DAM : 1640. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 35.15 m
MAXIMUM VOLUME OF RESERVOIR : 18200. m3x10E6
SURFACE AREA OF RESERVOIR : 2155.00 km2
LONGEST DIMENSION OF RESERVOIR : 250.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Flood plain sandy and silty alluvium, limestone bedrock (highly fissured on left bank)
SITE GEOLOGY : Carbonate
PERMEABILITY OF ROCKS : Limestone: 17 m/day to 600 m/day; high
GEOLOGY REFERENCES : 106, 152, 330A

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Kakki


DAM NAME : Kakki
COUNTRY : India
RIVER : Kakki
LOCATION OF CENTER OF RESERVOIR : 10.28N,77.17E
PROVINCE OR REGION : Kerala
DAM TYPE : Gravity
DATE DAM COMPLETED : 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 110 m above ground
STRUCTURAL HEIGHT OF DAM : 114. m
LENGTH OF DAM : 336. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 96.00 m
MAXIMUM VOLUME OF RESERVOIR : 447. m3x10E6
NOTES ON REGIONAL GEOLOGY : Metamorphic with igneous intrusions
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Pre-cambrian
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 106
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Kama


DAM NAME : Kama
RESERVOIR NAME : Kamskoye Vdkhr.
COUNTRY : USSR
RIVER : Kama
LOCATION OF CENTER OF RESERVOIR : 58.87N, 56.25E
LOCATION OF DAM : 58.09N, 56.32E
PROVINCE OR REGION : Ural
DAM TYPE : Earth () buttress and concrete gravity spillway section
DATE DAM COMPLETED : 1954
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Hydropower () is principal use
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 37. m
LENGTH OF DAM : 2300. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 35.15 m
MAXIMUM VOLUME OF RESERVOIR : 12200. m3x10E6
SURFACE AREA OF RESERVOIR : 1720.00 km2
LONGEST DIMENSION OF RESERVOIR : 230.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Wapplerite, limestone, dolomite, gypsum, anhydrite, all interlayered below alluvium
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 106,152,330A
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Kamafusa

DAM NAME : Kamafusa
COUNTRY : Japan
RIVER : Goishi
PROVINCE OR REGION : 20 km west of Sendai
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1970
DATE OF START OF FILLING : Feb-1970
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 47. m
LENGTH OF DAM : 177. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 42.30 m
MAXIMUM VOLUME OF RESERVOIR : 45. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Volcanic tuff. Hot spring downstream from dam; discharge rate and temperature increased after reservoir impoundment.
SITE GEOLOGY : Volcanic
NOTES ON HYDROLOGY : Groundwater apparently related to fractures in volcanic tuff. Deep circulation suggested by increased temperature and flow from nearby hot spring after impoundment.
TYPE OF PERMEABILITY : fracture
DATE OF FIRST SUSPECTED RIS EVENT : Apr-1970
NOTES ON SEISMICITY BEFORE IMPOUNDMENT : High frequency of macro-earthquakes near dam prior to filling.
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Microearthquake activity near to of under reservoir increased subsequent to impoundment. Highest levels of seismicity correspond to highest water levels.  Macroseismicity continues unchanged at high level.
GENERAL NOTES : Data reliability is low to moderate. Base-line data were not obtained. Definite increase in frequence of microeqrthquakes occurred after reservoir impoundment. Variation in activity accompanied changes in water level.
RIS CATEGORY : Accepted
TYPE OF  RIS : micro
GEOLOGY REFERENCES : 107,203,439

Kamishiiba

DAM NAME : Kamishiiba
COUNTRY : Japan
RIVER : Mimi
LOCATION OF CENTER OF RESERVOIR : 32.50N, 131.28E
LOCATION OF DAM : 32.50N, 131.30E
PROVINCE OR REGION : Miyazaki
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1955
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 103 m above ground
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 110. (m) above found
LENGTH OF DAM : 341. m
MAXIMUM DEPTH OF RESERVOIR : 100.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 100.00 m
MAXIMUM VOLUME OF RESERVOIR : 92. m3x10E6
SURFACE AREA OF RESERVOIR : 2.66 km2
LONGEST DIMENSION OF RESERVOIR : 3.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Mesozoic graywacke, clay-slate, overlain locally by welded tuff
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Mesozoic
GEOLOGY REFERENCES : 106, 316, 367, 468A

Kapchagay

DAM NAME : Kapchagay
RESERVOIR NAME : Kapchagayskoye Vdkhr.
COUNTRY : USSR
RIVER : Ili
LOCATION OF CENTER OF RESERVOIR : 43.80N, 77.83E
LOCATION OF DAM : 43.20N, 77.14E
PROVINCE OR REGION : Kazakhstan
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1970
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 50. m
LENGTH OF DAM : 470. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 47.50 m
MAXIMUM VOLUME OF RESERVOIR : 28140. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 130.0 km
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Quaternary alluvium and colluvium up to 20 m thick, underlain by quartz porphyry and granite porphyry
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106, 330A

Karadj (Amir Kabir)

DAM NAME : Karadj (Amir Kabir)
RESERVOIR NAME : Karadj (Karaj)
COUNTRY : Iran
RIVER : Karadj
LOCATION OF CENTER OF RESERVOIR : 35.98N, 51.11E
PROVINCE OR REGION : Markazi
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1961
DATE OF START OF FILLING : Aug-1960
RATE OF INITIAL FILLING : Average 7.20 (m/month) m/month rise in reservoir level
YEARS FROM BEGINNING TO MAXIMUM FILL : 1.90 (years) years
MAXIMUM RATE OF FILLING : April-June-1961.00 (m/month): 13.3 m/month
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () and public water supply are primary purposes, hydropower is secondary.
NOTES ON DAM : 168 m above ground
ORIENTATION OF RESERVOIR : N20E
STRUCTURAL HEIGHT OF DAM : 180. (m) above lowest foundation
MAXIMUM DEPTH OF RESERVOIR : 165.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 165.00 m
MAXIMUM VOLUME OF RESERVOIR : 205. m3x10E6
SURFACE AREA OF RESERVOIR : 4.00 km2
LONGEST DIMENSION OF RESERVOIR : 14.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam: Coarse-grained diorite sill same 360 m thick, dipping about 40 deg downstream
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : N70W to N85E
DIP OF PREDOMINANT FAULTING : 60N to vertical
MAXIMUM LENGTH OF FAULTS : 170.00 (km) km
DOMINANT SIDE UP : N (); north
PREDOMINANT FRACTURE ORIENTATION : N50W to N80E
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Downthrown block
NAME OF CLOSEST KNOWN FAULT : Musha
DISTANCE TO CLOSEST KNOWN FAULT : 3.0 (km) km N of reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Plio-Pleistocene deposits displaced
ARE LOCAL FAULTS ACTIVE? : Yes
GEOLOGY REFERENCES : 46, 106, 318, 448, 465

Kariba

DAM NAME : Kariba
RESERVOIR NAME : Lake Kariba
COUNTRY : Rhodesia/Zambia
RIVER : Zambesi
LOCATION OF CENTER OF RESERVOIR : 16.93S,27.93E
LOCATION OF DAM : 17.53S,28.75E
PROVINCE OR REGION : Mashonaland (Rhodesia)
DAM TYPE : Double curvature concrete arch
DATE DAM COMPLETED : 1959
DATE OF START OF FILLING : Dec-1958
RATE OF INITIAL FILLING : 1.25 (m/month) m/month
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Less than 8 m/yr (1964-1968); Hydropower
NOTES ON DAM : Dam height of 125 m above ground
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 128. m
LENGTH OF DAM : 617. m
MAXIMUM DEPTH OF RESERVOIR : 122.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 122.00 m
MAXIMUM VOLUME OF RESERVOIR : 175000. m3x10E6
SURFACE AREA OF RESERVOIR : 6572.00 km2
LONGEST DIMENSION OF RESERVOIR : 260.0 km
NOTES ON REGIONAL GEOLOGY : Mid-Zambesi trough; Mesozoic terrestrial deposits overlying Precambrian metamorphics. Active faults present, late Paleozoic to Cenozoic.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : PreCambrian
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Coarse-grained gneiss, steeply dipping, NE foliation. Cut by p-C pegmatites and J dolerites. Reservir impounded on upper Paleozoic to lower Mesozoic Karoo Series (ss, congl. mudst., 20 deg NE-SW)
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : lower Mesozoic
NOTES ON FAULTING : Active or possibly active faults located along the southwest and southeast margins of the lake; these are, respectively, the Deka and Binga faults.
PREDOMINANT FAULT TYPE : normal right
AZIMUTH OF PREDOMINANT FAULTING : NE
DIP OF PREDOMINANT FAULTING : 50N to 65N
MAXIMUM LENGTH OF FAULTS : 320.00 (km) km (Deka fault)
DOMINANT SIDE UP : S (); south
LOCATION OF RESERVOIR IN RELATION TO FAULTS : upthrown block
NAME OF CLOSEST KNOWN FAULT : Deka fault
DISTANCE TO CLOSEST KNOWN FAULT : 1.0 (km) km or less
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Holocene
ARE LOCAL FAULTS ACTIVE? : Yes
NOTES ON HYDROLOGY : Low permeability except for upper Karoo Series (escarpment grit) and Sijarira Series, which underlies the Karo Series. Deep, high permeability along faults is evidenced by numerous hot springs. Water table generally close to the surface.
PERMEABILITY OF ROCKS : low
TYPE OF PERMEABILITY : fracture
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : Jun-1959
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 6.25 (ISC)

DATE OF LARGEST SUSPECTED RIS EVENT : 23-Sep-1963

NOTES ON SEISMICITY AFTER IMPOUNDMENT : Weak correlation between increased macroseismicity and water levels; no increase in macroseismicity upon initial impoundment. Strong correlation between microseismicity and water level changes. All seismicity located under or very near to reservoir.

GENERAL NOTES : Data reliability is moderate to high. Seismic frequency and energy release are relatively high in the two years subsequent to the reservoir attaining maximum water levels. The largest event occurred as the reservoir attained maximum level.

RIS CATEGORY : accepted

TYPE OF RIS : macro and micro

GEOLOGY REFERENCES : 26, 59, 64, 106, 116, 133, 153, 184, 185, 186, 201, 203, 221, 260, 331, 393, 418, 420, 421, 428, 440, 477

Karun (Reza Shah Kabir)

DAM NAME : Karun (Reza Shah Kabir)
COUNTRY : Iran
RIVER : Karun
LOCATION OF DAM : 32.16N,49.52E
PROVINCE OR REGION : Khuzestan
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1976
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 200. m
LENGTH OF DAM : 380. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 170.00 m
MAXIMUM VOLUME OF RESERVOIR : 2900. m3x10E6
NOTES ON REGIONAL GEOLOGY : Eastern flank of Zagros Mountains. Deformed Mesozoic and Cenozoic sedimentary units.
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : Cenozoic
TECTONIC PROVINCE : Zagros Mountains
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
ORIENTATION OF STRUCTURAL GRAIN : NW (); northwest trending
DEGREE OF DEFORMATION : strongly deformed
NOTES ON FAULTING : Three principal reverse faults, at least two with Quaternary displacement (Masjed Soleyman fault and unnamed fault)
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : NW
DIP OF PREDOMINANT FAULTING : N10E to N30E () NE
MAXIMUM LENGTH OF FAULTS : 90.00 km
DOMINANT SIDE UP : N (); north
PREDOMINANT FRACTURE ORIENTATION : NW
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block () of Quaternary fault
NAME OF CLOSEST KNOWN FAULT : unnamed
DISTANCE TO CLOSEST KNOWN FAULT : 5.0 (km) km or less to SW
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary
GEOLOGY REFERENCES : 46,108,341,436,499

**Kastraki (Roi Constantine)**

DAM NAME : Kastraki (Roi Constantine)
RESERVOIR NAME : Kastraki
COUNTRY : Greece
RIVER : Acheloos
LOCATION OF CENTER OF RESERVOIR : 38.67N,21.70E
LOCATION OF DAM : 38.67N,21.70E
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1969
DATE OF START OF FILLING : Jan-1969
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 96. m
LENGTH OF DAM : 516. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 91.20 m
MAXIMUM VOLUME OF RESERVOIR : 1. m3x10E6
NOTES ON REGIONAL GEOLOGY : In the center zone of 3 generally north-trending zones separated by thrust faults that have been thrust to the west. Approximately 80 km north of Anatoli transform fault.
REGIONAL STRESS REGIME : Shear () and compressional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Teritary flysch deposits of calcareous conglomerate and siltstone, locally karstic solution features. Reservoir impounded on Cretaceous limestone, cavernous; and a Cretaceous assemblage of shale, limestone and siliceous limestone. Bedding is flat-lyig to 25 deg east dipping.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Cretaceous
DEGREE OF DEFORMATION : shallow dipping
DATE OF FIRST SUSPECTED RIS EVENT : 12-Mar-1969
DATE OF LARGEST SUSPECTED RIS EVENT : 4.6
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Kastraki associated seismicly with nearby Kremasta reservoir. Increase in macroseismicity in the immediate reservoir area following impoundment.
GENERAL NOTES : Data are insufficiently detailed to treat Kastraki independently of Kremasta.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 107,131,181,454

**Kawamata**

DAM NAME : Kawamata
COUNTRY : Japan
RIVER : Kinu
LOCATION OF CENTER OF RESERVOIR : 36.88N,139.51E
PROVINCE OR REGION : Tochigi
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
NOTES ON DAM : Dam height of 112 m above ground
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 120. m
LENGTH OF DAM : 137. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 102.00 m
MAXIMUM VOLUME OF RESERVOIR : 88. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Tuff
SITE GEOLOGY : Volcanic
GEOLOGY REFERENCES : 106,289

Keban

DAM NAME : Keban
COUNTRY : Turkey
RIVER : Firat (Euphrates)
LOCATION OF CENTER OF RESERVOIR : 38.82N, 39.33E
LOCATION OF DAM : 38.78N, 38.72E
DAM TYPE : Concrete gravity () with rockfill section
DATE DAM COMPLETED : 1973
DATE OF START OF FILLING : May-1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 163 m above ground
ORIENTATION OF RESERVOIR : S80E
STRUCTURAL HEIGHT OF DAM : 212. (m) above foundation
LENGTH OF DAM : 1097. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 182.00 m
MAXIMUM VOLUME OF RESERVOIR : 31000. m3x10E6
SURFACE AREA OF RESERVOIR : 680.00 km2
LONGEST DIMENSION OF RESERVOIR : 17.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam: Paleozoic calc-schist, mica schist, chlorite schist, marble incl. karstified carbonates. Reservoir: igneous, metamorphic, and sedimentary rocks. Faults in foundation; N5-10W, 80-90 NE
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Paleozoic
NOTES ON FAULTING : Faults trending north and east are present, along with complex fracture systems. Typically normal faulting; some faults are reported to be active. Right lateral North Anatolian fault some 100 km north, and an unnamed fault to the south.
NOTES ON HYDROLOGY : Flat groundwater gradient is related to karstic development, which typically exhibits high transmissibility. Local perched water table related to clay infilling in the karst and presence of schist. Springs present up- and down-stream from the dam.
TYPE OF PERMEABILITY : Cavernous () within calcareous terrane.
DATE OF FIRST SUSPECTED RIS EVENT : Jun-1973
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No clear influence of reservoir on macroseismicity. Microseismicity under or very near reservoir upon initial impoundment; some relationship to water level changes indicated.
GENERAL NOTES : Data reliability is good; number of seismic events increased subsequent to increase in reservoir level and decreased with decrease in reservoir level.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 108, 149, 181, 289, 418, 458, 485,

Kemer

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DAM NAME : Kemer
COUNTRY : Turkey
RIVER : Akcay
LOCATION OF CENTER OF RESERVOIR : 37.57N,28.61E
LOCATION OF DAM : 37.47N,28.52E
PROVINCE OR REGION : Aydin
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1958
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () listed first
NOTES ON DAM : Dam height of 104 m above ground
ORIENTATION OF RESERVOIR : S25E
STRUCTURAL HEIGHT OF DAM : 114. m
LENGTH OF DAM : 310. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 96.00 m
MAXIMUM VOLUME OF RESERVOIR : 544. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 26.0 km
NOTES ON REGIONAL GEOLOGY : Turkish metamorphic system, Mesozoic
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism (), tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Oldest Turkish metamorphic system, mica-schists. Phyllites, marble, schistose limestone, underlying Tertiary
marls, clays, and siltstones
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Tertiary
GEOLOGY REFERENCES : 106,468A
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Kenney

DAM NAME : Kenney
RESERVOIR NAME : Lake Nechako or Tahtsa Lake
COUNTRY : Canada
RIVER : Nechako
LOCATION OF CENTER OF RESERVOIR : 53.43N,125.57W
LOCATION OF DAM : 53.62N,124.97W
PROVINCE OR REGION : British Columbia
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1952
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Two principal arms, both generally E-W
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 107. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 96.30 m
MAXIMUM VOLUME OF RESERVOIR : 22000. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 180.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Basalt
SITE GEOLOGY : Volcanic
GEOLOGY REFERENCES : 106,289

Kerr

DAM NAME : Kerr
RESERVOIR NAME : Flathead Lake
COUNTRY : USA
RIVER : Flathead
LOCATION OF CENTER OF RESERVOIR : Dam 47.70N, 114.17W
LOCATION OF DAM : Reservoir 47.89N, 114.11W
PROVINCE OR REGION : Montana
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1958 () dam completed
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 57m above ground.
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 60. m
LENGTH OF DAM : 244. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 54.00 m
MAXIMUM VOLUME OF RESERVOIR : 1505. m3x10E6
SURFACE AREA OF RESERVOIR : 60.00 (km2) sq km
LONGEST DIMENSION OF RESERVOIR : 40.0 (km) km
NOTES ON REGIONAL GEOLOGY : Near the center of the Idaho Batholith of Precambrian age.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Precambrian
TECTONIC PROVINCE : Intermountain seismic belt
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Dam and reservoir foundation: dam underlain by Pleistocene clastic sediments. Reservoir underlain by Precambrian Beltian series (metasedimentary rock). Reservoir located in a graben, the age of which was not obtained.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : PreCambrian
NOTES ON FAULTING : North-trending faults define the graben in which Flathead Lake is impounded. Age of most recent displacement is late Cenozoic. Northwest-trending faults (time and type of displacement not obtained) are present north and south of the dam and reservoir.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N
MAXIMUM LENGTH OF FAULTS : 85.00 (km) km
DOMINANT SIDE UP : E (); east
LOCATION OF RESERVOIR IN RELATION TO FAULTS : downthrown block
DATE OF FIRST SUSPECTED RIS EVENT : 9-Oct-1964
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.9 Mb (NOAA)
DATE OF LARGEST SUSPECTED RIS EVENT : 28-Jul-1971
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Clear increase in frequency of macroseismicity begining six years after impoundment. Relation with water levels unclear. Magnitude 4.6 m beneath reservoir in October 1964, and 4.9 in July 1971.
GENERAL NOTES : Weak case of reservoir induced seismicty.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 106, 135, 203, 418

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Khantaika


DAM NAME : Khantaika
RESERVOIR NAME : Khantayskoye Vdkhr.
COUNTRY : USSR
RIVER : Khantaika
LOCATION OF CENTER OF RESERVOIR : 68.22N,88.28E
LOCATION OF DAM : 68.08N,87.45E
PROVINCE OR REGION : Krasnoyarsk
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1970
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Principal arms of reservoir are NW and S from dam.
ORIENTATION OF RESERVOIR : N40E
STRUCTURAL HEIGHT OF DAM : 65. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 61.75 m
MAXIMUM VOLUME OF RESERVOIR : 23500. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 140.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 107
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Kinarsani

DAM NAME : Kinarsani
RESERVOIR NAME : Kinarsani
COUNTRY : India
RIVER : Kinarsani
LOCATION OF CENTER OF RESERVOIR : 17.68N, 80.67E
LOCATION OF DAM : 17.68N, 80.67E
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 61.75 m
NOTES ON REGIONAL GEOLOGY : Margin of the Peninsular Shield of India; pre-Cambrian metamorphics as well as younger sediments and volcanics
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GENERAL NOTES : Insufficient data aavailable to evaluate. One macro earthquake of magnitude 5.3 (ISC), 14 kilometers from reservoir center in April 1969
RIS CATEGORY : Questionable
TYPE OF RIS : micro
GEOLOGY REFERENCES : 192, 195, 198, 203

Kolnbrein

DAM NAME : Kolnbrein
COUNTRY : Austria
PROVINCE OR REGION : Kaernten
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1977
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 200. m
LENGTH OF DAM : 626. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 170.00 m
MAXIMUM VOLUME OF RESERVOIR : 200. m3x10E6
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 107, 108, 472

Kops

DAM NAME : Kops
COUNTRY : Austria
RIVER : Ill
PROVINCE OR REGION : Voralberg
DAM TYPE : Concrete arch () with gravity section
DATE DAM COMPLETED : 1965
DATE OF START OF FILLING : Filling began in August 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 105 m aove ground
STRUCTURAL HEIGHT OF DAM : 122. m
LENGTH OF DAM : 400. m
MAXIMUM DEPTH OF RESERVOIR : 103.0 (m) (determined from diagrams)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 103.00 m
MAXIMUM VOLUME OF RESERVOIR : 45. m3x10E6
SURFACE AREA OF RESERVOIR : 1.00 km2
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Amphibolite and aplite, highly fissured near surface, attitude variable
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,164,176

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Kossou

DAM NAME : Kossou
COUNTRY : Ivory Coast
RIVER : Bandama Blanc
LOCATION OF CENTER OF RESERVOIR : 7.36N,5.66E
LOCATION OF DAM : 6.79N,5.47E
PROVINCE OR REGION : Bouake
DAM TYPE : Earth () and rock fill
DATE DAM COMPLETED : 1972
RATE OF INITIAL FILLING : 1.08 (m/month) m/month
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 57. m
LENGTH OF DAM : 1500. m
MAXIMUM DEPTH OF RESERVOIR : 52.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 52.00 m
MAXIMUM VOLUME OF RESERVOIR : 28750. m3x10E6
SURFACE AREA OF RESERVOIR : 1684.00 km2
LONGEST DIMENSION OF RESERVOIR : 135.0 km
NOTES ON REGIONAL GEOLOGY : Ancient river basin, possibly in existence since beginning of Paleozoic
REGIONAL GEOLOGY : Coarse clastic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Arkose, sandstone, and mudstone of the Voltaian series
SITE GEOLOGY : Coarse clastic
GEOLOGY REFERENCES : 51,306,344
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Koyna

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DAM NAME : Koyna
RESERVOIR NAME : Shivaji Sagar Lake
COUNTRY : India
RIVER : Koyna
LOCATION OF CENTER OF RESERVOIR : 17.62N,73.76E
LOCATION OF DAM : 17.40N,73.75E
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1962
DATE OF START OF FILLING : Jun-1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 103. m
LENGTH OF DAM : 853. m
MAXIMUM DEPTH OF RESERVOIR : 100.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 100.00 m
MAXIMUM VOLUME OF RESERVOIR : 2780  m3x10E6
SURFACE AREA OF RESERVOIR : 115.00 km2
LONGEST DIMENSION OF RESERVOIR : 33.0 km
NOTES ON REGIONAL GEOLOGY : Volcanic platform of Deccan Trap, up to 2000 m thick volcanic sequence overlying peninsular shield of
Archean Gondwana rocks. Age of Deccan volcanics ranges from Cretaceous to Eocene-Oligocene
REGIONAL GEOLOGY : Volcanic
AGE OF REGIONAL GEOLOGY : Cretaceous to Oligocene
TECTONIC PROVINCE : Deccan Trap, Indian Peninsula
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Massive basalt with interbedded vesicular and amygdaloidal basalt and ash beds of late Cretaceous to Eocene
Deccan Trap deposits. Extensive fissures and fractures.  Bedding horizontal.
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Late Cretaceous to Eocene
DEGREE OF DEFORMATION : Flatlying
NOTES ON FAULTING : Fault displacement has occurred during historical time along the zone that ruptured during the 1967 event.
Offset walls suggest that 1 m of left-lateral displacement has occurred during historical time.  Fault plane solutions of 1967 event
suggest left slip on a near-vertical plane. N-trending fault with 3- to 5-m wide gouge zone trends through dam.
PREDOMINANT FAULT TYPE : Left-slip (), minor normal component.
AZIMUTH OF PREDOMINANT FAULTING : More or less N to S
DIP OF PREDOMINANT FAULTING : Near-vertical
DOMINANT SIDE UP : E (); east.
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block
NAME OF CLOSEST KNOWN FAULT : Unnamed fault
DISTANCE TO CLOSEST KNOWN FAULT : 5.0 (km) km of dam
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Historic(?)
RATE OF SLIP ON LOCAL FAULTS : 0.5cm/yr
ARE LOCAL FAULTS ACTIVE? : Yes
NOTES ON HYDROLOGY : The extensive fractures and fissures possibly act as feeders for deep circulation of water, evidenced by hot
springs in the west coast.  Some nearby springs show order-of-magnitude flow increases following reservoir impoundment.  Relief
around 500 m
PERMEABILITY OF ROCKS : Low
TYPE OF PERMEABILITY : Fracture
GROUNDWATER GRADIENT : Medium
DEGREE OF TOPOGRAPHIC RELIEF : High
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DATE OF FIRST SUSPECTED RIS EVENT : Oct-1963
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : 6.5
DATE OF LARGEST SUSPECTED RIS EVENT : 10-Dec-1967
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Seismicity increased following initial increase to a particular water level, with 3- to 6-month lag time. Reduced seismic activity occurred during periods of slow filling. Recurring fill to similar heights after drawdown did not result in similar frequency of seismic events. 1967 event occurred within reservoir area; smaller events within 25 km of dam, most downstream. Focal depths typically less than 15 km.
GENERAL NOTES : Data reliability is moderate to good. Absence of pre-impoundment data. Most events clustered around reservoir. The number of events increased subsequent to impoundment.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 11, 15, 16, 17, 20, 27, 33, 35, 35A, 36, 37, 47, 50, 93, 95, 101, 109, 122, 136, 137, 169, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 201, 202, 204, 225, 238, 263, 323, 327, 329, 361, 377, 398, 419, 429, 447

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Krasnoyarsk


DAM NAME : Krasnoyarsk
COUNTRY : USSR
RIVER : Yenisei
LOCATION OF CENTER OF RESERVOIR : 55.00N,96.00E
LOCATION OF DAM : 55.89N,97.31E
PROVINCE OR REGION : Krasnoyarsk
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 124. m
LENGTH OF DAM : 1065. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 106.00 m
MAXIMUM VOLUME OF RESERVOIR : 73300. m3x10E6
SURFACE AREA OF RESERVOIR : 2130.00 km2
LONGEST DIMENSION OF RESERVOIR : 250.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Granite with veined porphyrites; shear zone at dam site has mylonitized and brecciated porphyrite and
granite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,152,289,330A
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DAM NAME : Kremasta        (Roi Paul)
RESERVOIR NAME : Lake Kremasta
COUNTRY : Greece
RIVER : Acheloos
LOCATION OF CENTER OF RESERVOIR : 38.90N,21.53E
LOCATION OF DAM : 39.87N,21.50E
PROVINCE OR REGION : Etolo-Acarnanie
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1965
DATE OF START OF FILLING : 21-Jul-1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower () and Irrigation
NOTES ON DAM : Dam height of 150 m above ground.  Reservoir is V-shaped.
STRUCTURAL HEIGHT OF DAM : 160. m
LENGTH OF DAM : 460  m
MAXIMUM DEPTH OF RESERVOIR : 120.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 120.00 m
MAXIMUM VOLUME OF RESERVOIR : 4750. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 28.0 km
NOTES ON REGIONAL GEOLOGY : In the center zone of three generally north-trending zones separated by thrust faults that have been
thrust to the west.  Approximately 80 km north of Anatoli transform fault.
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense (), tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Eocene flysch deposits of calcareous conglomerate and siltstone.  Local karstic solution features.
Reservoir impounded on the flysch deposits and a Jurassic and Cretaceous assemblage of shale, limestone, and siliceous limestone.
Bedding is flat-lying to 25 degrees east-dipping.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Eocene
DEGREE OF DEFORMATION : shallow dipping
NOTES ON FAULTING : Two thrust faults of Miocene age pass through the reservoir, as does the left-lateral Alevrada-Smardacha fault.
The thrust faults have thick mylonite zones with halite that daylight into the reservoir.  Conjugate ENE-trending wrench faults are
present approximately 10 km north of the dam.
PREDOMINANT FAULT TYPE : strike-slip
NAME OF CLOSEST KNOWN FAULT : Alevrada-Smardacha
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km
NOTES ON HYDROLOGY : Irregular permeability controlled by the Pindus limestones with faults acting both as conduits and barriers.
Flysch mostly acts as groundwater barrier except where underlain by the Pindus limestones.
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : Aug-1965
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 6.3
DATE OF LARGEST SUSPECTED RIS EVENT : 24-Jan-1966
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Clear correlation at both macro and micro level to initial impoundment.  Frequency increased
particularly during rapid rise.  Activity continued subsequent to initial filling with no clear correlation to water level changes.
GENERAL NOTES : Data reliability is good.  The area had recorded pre-impoundment seismicity; however, post-impoundment events
localized in reservoir area.
RIS CATEGORY : Accepted
TYPE OF  RIS : macro and micro
GEOLOGY REFERENCES : 64,106,110,131,153,159,160,201,203,331,353,354,355,393,418,426,454
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Kremenchug


DAM NAME : Kremenchug
RESERVOIR NAME : Kremenchugskoye Vdkhr.
COUNTRY : USSR
RIVER : Dnieper
LOCATION OF CENTER OF RESERVOIR : 49.33N,32.50E
LOCATION OF DAM : 49.11N,33.17E
PROVINCE OR REGION : Ukraine
DAM TYPE : Earth () buttress and concrete gravity spillway section
DATE DAM COMPLETED : 1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Hydropower () is principal use
ORIENTATION OF RESERVOIR : N60W
STRUCTURAL HEIGHT OF DAM : 33. m
LENGTH OF DAM : 12144. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 31.35 m
MAXIMUM VOLUME OF RESERVOIR : 13500. m3x10E6
SURFACE AREA OF RESERVOIR : 2500.00 km2
LONGEST DIMENSION OF RESERVOIR : 130.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Alluvium up to 92 ft thick overlying porphyritic granite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,152,306,330A
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Kuma

DAM NAME : Kuma
COUNTRY : USSR
RIVER : Kuma
PROVINCE OR REGION : Karelia
DAM TYPE : Earth () and gravity
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 20. (m) for earth section
LENGTH OF DAM : 2300. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 19.00 m
MAXIMUM VOLUME OF RESERVOIR : 10800. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Fissured magmatites and gneiss with granite intrusions, overlain by up to 10 m of moraine deposits
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,330A

Kurobe

DAM NAME : Kurobe
RESERVOIR NAME : Lake Kurobe
COUNTRY : Japan
RIVER : Kurobe
LOCATION OF CENTER OF RESERVOIR : 36.53N, 137.65E
LOCATION OF DAM : 36.56N, 137.67E
DAM TYPE : Concrete Arch
DATE DAM COMPLETED : 1960
DATE OF START OF FILLING : Mar-1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S30E
STRUCTURAL HEIGHT OF DAM : 186. (m) above found.
LENGTH OF DAM : 489. m
MAXIMUM DEPTH OF RESERVOIR : 180.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 180.00 m
MAXIMUM VOLUME OF RESERVOIR : 149. m3x10E6
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Granite.
SITE GEOLOGY : Batholithic
DATE OF FIRST SUSPECTED RIS EVENT : 19-Aug-1961
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.9 (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 19-Aug-1961
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Good correlation between impoundment and seismicity. Increase and decrease in water level is followed almost immediately by increase and decrease in earthquake frequency.
GENERAL NOTES : Data reliability is good; based on correlation of activity with change in reservoir levels.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 106, 210, 246

Kuzuryu

DAM NAME : Kuzuryu
COUNTRY : Japan
RIVER : Kuzuryu
LOCATION OF CENTER OF RESERVOIR : 35.89N, 136.71E
PROVINCE OR REGION : Fukui
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower () and flood control
NOTES ON DAM : Dam height of 118 m above ground
STRUCTURAL HEIGHT OF DAM : 128. (m) above foundation
LENGTH OF DAM : 355. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 115.20 m
MAXIMUM VOLUME OF RESERVOIR : 320. m3x10E6
SURFACE AREA OF RESERVOIR : 8.90 km2
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Phyllitic slate, conglomerate, tuffaceous sandstone and shale
SITE GEOLOGY : Coarse clastic
GEOLOGY REFERENCES : 106,233

La Angostura

DAM NAME : La Angostura

COUNTRY : Mexico

RIVER : Grijalva

LOCATION OF DAM : 16.43N,92.78W

PROVINCE OR REGION : Chiapas

DAM TYPE : Rock () fill

DATE DAM COMPLETED : 1974

EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower

NOTES ON DAM : Maximum volume of 18000 E6 cubic meters is planned after second stage completed.

ORIENTATION OF RESERVOIR : S

STRUCTURAL HEIGHT OF DAM : 146. m

MAXIMUM DEPTH OF RESERVOIR : 128.0 (m) (estimated from drawings)

RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 128.00 m

MAXIMUM VOLUME OF RESERVOIR : 9200. m3x10E6

NOTES ON REGIONAL GEOLOGY : Horst and graben structure as viewed from south to north across Mexico. Regional normal faults. Area is part of Chiapas Plateau, north of Sierra Madre del Sur and subduction zone

REGIONAL STRESS REGIME : Extensional

EVIDENCE FOR REGIONAL STRESS REGIME : tectonics

CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium

NOTES ON SITE GEOLOGY : Jurassic and Cretaceous limestone, clayey limestone, and minor shale, striking roughly east-west and folded regionally

SITE GEOLOGY : Carbonate

AGE OF SITE GEOLOGY : Jurassic

PREDOMINANT FAULT TYPE : Normal

LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block

GEOLOGY REFERENCES : 107,294

La Cohilla

DAM NAME : La Cohilla
COUNTRY : Spain
RIVER : Nansa
LOCATION OF CENTER OF RESERVOIR : 43.12N, 4.54W
PROVINCE OR REGION : Santander
DAM TYPE : Arch
DATE DAM COMPLETED : 1950
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 93 m above ground.
STRUCTURAL HEIGHT OF DAM : 116. (m) m
LENGTH OF DAM : 290. (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 98.00 m
MAXIMUM VOLUME OF RESERVOIR : 12. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GENERAL NOTES : Insufficient data available to evaluate. Only one macro earthquake of unknown magnitude located 19 km from dam in 1975 by ISC.
RIS CATEGORY : Questionable
GEOLOGY REFERENCES : 72A, 106

La Fuensanta

DAM NAME : La Fuensanta
RESERVOIR NAME : La Fuensanta
COUNTRY : Spain
RIVER : Segura
LOCATION OF CENTER OF RESERVOIR : 38.38N, 2.23W
PROVINCE OR REGION : Albacete
DAM TYPE : Gravity
DATE DAM COMPLETED : 1933
NOTES ON HISTORY OF IMPOUNDMENT : Reservoir may have been refilled in 1973.
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (), hydropower, and flood control.
NOTES ON DAM : Dam height of 75 m above ground.
STRUCTURAL HEIGHT OF DAM : 83. m
LENGTH OF DAM : 232. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 74.70 m
MAXIMUM VOLUME OF RESERVOIR : 235. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 11.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
DATE OF FIRST SUSPECTED RIS EVENT : May-1973
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Event reported after an apparent refilling of the reservoir in 1973. No other data obtained.
GENERAL NOTES : Insufficient data available to evaluate. Macroearthquakes offset to east of dam by 20 km.
RIS CATEGORY : Questionable
GEOLOGY REFERENCES : 72A, 106

## Lake de Smet

DAM NAME : Lake de Smet
RESERVOIR NAME : Lake de Smet
COUNTRY : USA
LOCATION OF CENTER OF RESERVOIR : 44.47N,106.60W
PROVINCE OR REGION : Wyoming
DAM TYPE : Earth
DATE DAM COMPLETED : 1971
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : SE
STRUCTURAL HEIGHT OF DAM : 146. (m) above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 131.40 m
MAXIMUM VOLUME OF RESERVOIR : 116. m3x10E6
SURFACE AREA OF RESERVOIR : 9.70 km2
LONGEST DIMENSION OF RESERVOIR : 6.0 (km) km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 107

Las Portas

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DAM NAME : Las Portas
COUNTRY : Spain
RIVER : Camba
LOCATION OF CENTER OF RESERVOIR : 42.10N,7.29W
PROVINCE OR REGION : Orense
DAM TYPE : Arch
DATE DAM COMPLETED : 1974
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 131. m
LENGTH OF DAM : 477. m
MAXIMUM DEPTH OF RESERVOIR : 127.0 (m) m (from diagram)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 127.00 m
MAXIMUM VOLUME OF RESERVOIR : 538. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 87,108
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Libby

DAM NAME : Libby
RESERVOIR NAME : Libby (Lake Koocanusa)
COUNTRY : USA
RIVER : Kootenai
LOCATION OF CENTER OF RESERVOIR : 48.52N,115.30W
LOCATION OF DAM : 48.42N,115.55W
PROVINCE OR REGION : Montana
DAM TYPE : Gravity () concrete
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 128. (m) above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 110.00 m
MAXIMUM VOLUME OF RESERVOIR : 6124. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 67.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 108
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Limberg

DAM NAME : Limberg
RESERVOIR NAME : Wasserfallboden
COUNTRY : Austria
RIVER : Kapruner Ache
LOCATION OF CENTER OF RESERVOIR : 47.18N,12.72E
LOCATION OF DAM : 47.20N,12.72E
PROVINCE OR REGION : Salzburg
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1951
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 102 m above ground level
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 120. m
LENGTH OF DAM : 350. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 102.00 m
MAXIMUM VOLUME OF RESERVOIR : 86. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 3.0 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Carboniferous to Triassic calc-mica schist in an ice-furrowed gorge.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Triassic
GEOLOGY REFERENCES : 106,468A

Limmern

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DAM NAME : Limmern
RESERVOIR NAME : Limmernsee
COUNTRY : Switzerland
RIVER : Limmernbach
LOCATION OF CENTER OF RESERVOIR : 46.82N,9.02E
LOCATION OF DAM : 46.83N,9.01E
PROVINCE OR REGION : Glarus
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 145. (m) above lowest foundation
LENGTH OF DAM : 375. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 127.00 m
MAXIMUM VOLUME OF RESERVOIR : 90. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 2.3 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Fissured calc-mica schist
SITE GEOLOGY : Metamorphic
MAXIMUM LENGTH OF FAULTS : 60.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : 8.0 (km) km
GEOLOGY REFERENCES : 106,289
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Liujiaxia (Liu Chiang)

DAM NAME : Liujiaxia (Liu Chiang)
COUNTRY : China (PRC)
RIVER : Huang He (Huang Ho)
LOCATION OF CENTER OF RESERVOIR : 35.93N,103.23E
LOCATION OF DAM : 36.07N,103.27E
PROVINCE OR REGION : Gansu (Kansu)
DAM TYPE : Gravity
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : 40 m maximum from 1969 to 1972; Hydropower
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 147. (m) above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 129.00 m
MAXIMUM VOLUME OF RESERVOIR : 5700. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 38.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Bedrock at dam is middle Precambrian micaceous quartz schist with some layers of hornblende schist, minor granite and lamprophyre dikes. Several faults and fractures in foundation.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Precambrian
GEOLOGY REFERENCES : 108,484

Lower Hell Hole

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DAM NAME : Lower Hell Hole
RESERVOIR NAME : Hell Hole
COUNTRY : USA
RIVER : Rubicon
LOCATION OF CENTER OF RESERVOIR : 39.07N,120.37W
PROVINCE OR REGION : California
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Dam height of 125m above ground
ORIENTATION OF RESERVOIR : N70E
STRUCTURAL HEIGHT OF DAM : 125. (m) m (from diagram)
MAXIMUM DEPTH OF RESERVOIR : 118.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 118.00 m
MAXIMUM VOLUME OF RESERVOIR : 257. m3x10E6
SURFACE AREA OF RESERVOIR : 5.00 km2
LONGEST DIMENSION OF RESERVOIR : 6.0 km
NOTES ON REGIONAL GEOLOGY : Regional includes Sierran granitics, limited outcrops of Jurassic marine strata, and Pliocene
pyroclastics
REGIONAL GEOLOGY : Batholithic
AGE OF REGIONAL GEOLOGY : Cretaceous
TECTONIC PROVINCE : Sierra Nevada
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Sierran granitics
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Cretaceous
NOTES ON FAULTING : Sierran frontal faults located 13 km to east, Foothills fault system 22 km west
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N25W
MAXIMUM LENGTH OF FAULTS : 33.00 (km) km
DOMINANT SIDE UP : W (); west
LOCATION OF RESERVOIR IN RELATION TO FAULTS : upthrown block
NAME OF CLOSEST KNOWN FAULT : Sierran frontal fault system
DISTANCE TO CLOSEST KNOWN FAULT : 13.0 (km) km east
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : late Tertiary
GEOLOGY REFERENCES : 106,121,235
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Luzzone

DAM NAME : Luzzone
COUNTRY : Switzerland
RIVER : Brenno di Luzzone
LOCATION OF CENTER OF RESERVOIR : 46.89N,8.97E
LOCATION OF DAM : 46.88N,8.95E
PROVINCE OR REGION : Ticino
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 208. m
LENGTH OF DAM : 530. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 178.00 m
MAXIMUM VOLUME OF RESERVOIR : 87. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 3.6 km
NOTES ON REGIONAL GEOLOGY : Pennine Alps Nappe. Mesozoic schist in contact with Soja Fm.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Jurassic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Jurassic-Cretaceous schist; contact with Soja Fm. on southeast side of lake. Thrust fault within 1 km on either side of reservoir.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Jurassic
ORIENTATION OF STRUCTURAL GRAIN : NE
DEGREE OF DEFORMATION : strongly deformed
NOTES ON FAULTING : Inter-nappe thrust fault generally strikes NE; however, mapped trace west of reservoir circles around. Left-lateral strike-slip fault mapped near reservoir; age unknown.
PREDOMINANT FAULT TYPE : Left-slip
AZIMUTH OF PREDOMINANT FAULTING : NE
MAXIMUM LENGTH OF FAULTS : 5.00 (km) km
DOMINANT SIDE UP : SE (); southeast
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block
DISTANCE TO CLOSEST KNOWN FAULT : 2.0 (km) km
GEOLOGY REFERENCES : 106,434

Mangalam

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DAM NAME : Mangalam
COUNTRY : India
RIVER : Cherukunna Puzha
LOCATION OF CENTER OF RESERVOIR : 10.63N,76.52E
LOCATION OF DAM : 10.63N,76.52E
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Dam height of 19m above ground
STRUCTURAL HEIGHT OF DAM : 30. m
LENGTH OF DAM : 1063. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 28.50 m
MAXIMUM VOLUME OF RESERVOIR : 25. m3x10E6
NOTES ON REGIONAL GEOLOGY : Margin of the Peninsular Shield of India
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SEISMICITY BEFORE IMPOUNDMENT : Pre-impoundment seismicity: 10 in region, max. VII at 10.8N, 76.8E, 1900 (Chandra, 1977)
GENERAL NOTES : Insufficient data available to evaluate.  No macroearthquakes reported by ISC near dam.
RIS CATEGORY : Questionable
TYPE OF  RIS : micro
GEOLOGY REFERENCES : 106,192,195,203
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## Maina di Sauris

DAM NAME : Maina di Sauris
RESERVOIR NAME : Lago di Sauris
COUNTRY : Italy
RIVER : Lumiei
LOCATION OF CENTER OF RESERVOIR : 46.40N, 12.85E
PROVINCE OR REGION : Udine
DAM TYPE : Concrete arch () dome
DATE DAM COMPLETED : 1947
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 134m above ground
STRUCTURAL HEIGHT OF DAM : 136. m
LENGTH OF DAM : 138. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 118.00 m
MAXIMUM VOLUME OF RESERVOIR : 73. m3x10E6
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dolomitized limestone
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 106, 289

Mangla

DAM NAME : Mangla
RESERVOIR NAME : Mangla
COUNTRY : Pakistan
RIVER : Jhelum
LOCATION OF CENTER OF RESERVOIR : 33.22N, 73.68E
LOCATION OF DAM : 33.13N, 73.67E
PROVINCE OR REGION : Punjab
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation () and hydropower
NOTES ON DAM : Dam height of 104m above ground; cross-shaped reservoir
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 116. (m) above lowest foundation
LENGTH OF DAM : 3353. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 104.40 m
MAXIMUM VOLUME OF RESERVOIR : 7250. m3x10E6
SURFACE AREA OF RESERVOIR : 253.00 km2
LONGEST DIMENSION OF RESERVOIR : 35.0 km
NOTES ON REGIONAL GEOLOGY : Himalayan belt, 170 km south of Himalayan boundary fault syntaxis. Regional units include Pleistocene deposits of Indo- Ganges Plain, Siwalks in fault contact with older Himalayan units.
REGIONAL GEOLOGY : Fine clastic
AGE OF REGIONAL GEOLOGY : Plio-Pleistocene
TECTONIC PROVINCE : Himalayan foothills
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Siltstone and clay of Plio-Pleistocene Siwalik Series folded into anticlines and synclines. Dips vary from 10 degrees to vertical beneath dam
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Plio-Pleistocene
DEGREF OF DEFORMATION : Strongly deformed
PREDOMINANT FAULT TYPE : Thrust
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Downthrown block
NAME OF CLOSEST KNOWN FAULT : Boundary fault
DISTANCE TO CLOSEST KNOWN FAULT : 50.0 (km) km from dam
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Holocene
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No clear spatial association of post-impoundment seismicity with reservoir. No change in level of macro seismicity. Widely scattered epicenters, focal depths not given.
GENERAL NOTES : Data reliability is low. Data indicate no definitive spatial or temporal relationships of seismic activity to reservoir impoundment.
RIS CATEGORY : Not RIS
GEOLOGY REFERENCES : 3, 5, 69, 106, 138, 413

Manicouagan 3

DAM NAME : Manicouagan 3
RESERVOIR NAME : Manic 3
COUNTRY : Canada
RIVER : Manicouagan
LOCATION OF CENTER OF RESERVOIR : 50.11N,68.65W
LOCATION OF DAM : 49.77N,68.62W
PROVINCE OR REGION : Quebec
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1975
DATE OF START OF FILLING : Aug-1975
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 108. (m) above lowest foundation
LENGTH OF DAM : 366. m
MAXIMUM DEPTH OF RESERVOIR : 96.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 96.00 m
MAXIMUM VOLUME OF RESERVOIR : 10423. m3x10E6
SURFACE AREA OF RESERVOIR : 207.00 km2
LONGEST DIMENSION OF RESERVOIR : 68.0 km
NOTES ON REGIONAL GEOLOGY : Precambrian metamorphic and igneous rocks of the Grenville Belt. Anorthosite intersected by numerous basic dikes.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : PreCambrian
TECTONIC PROVINCE : Canadian Shield
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Site geology: 220m of glaciofluvial outwash deposits of silt, sand, gravel and boulders overlying preCambrian anorthosite.
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : preCambrian
NOTES ON FAULTING : No known faults are present in the dam and reservoir area. Three sets of joints have been reported at the dam site, and a lineament has been identified near the concentration of post-impoundment seismicity.
DEGREE OF TOPOGRAPHIC RELIEF : moderate
DATE OF FIRST SUSPECTED RIS EVENT : 15-Sep-1975
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.1
DATE OF LARGEST SUSPECTED RIS EVENT : 23-Oct-1975
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Clear increase in macroseismicity at reservoir associated with initial impoundment; clear correlation of microseismic activity with impoundment, beginning one month after impoundment commenced.
GENERAL NOTES : Data reliability is moderate to good. Pre-impoundment data are not well documented. Post-impoundment seismicity occurred within the reservoir area after impoundment commenced. Good spatial and temporal correlation with reservoir impoundment.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 45,108,127A,132,275,364,365,424,425

Marathon

DAM NAME : Marathon
RESERVOIR NAME : Lake Marathon
COUNTRY : Greece
RIVER : Haradra
LOCATION OF CENTER OF RESERVOIR : 38.18N,23.90E
LOCATION OF DAM : 38.17N,23.90E
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1929
DATE OF START OF FILLING : 29-Oct-1929
MAXIMUM RATE OF DRAWDOWM : 1.00 (m/month) m/month in 1956-1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 67. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 60.30 m
MAXIMUM VOLUME OF RESERVOIR : 41. m3x10E6
SURFACE AREA OF RESERVOIR : 2.40 km2
LONGEST DIMENSION OF RESERVOIR : 5.0 (km) km
NOTES ON REGIONAL GEOLOGY : Attica basin; preCambrian metamorphics
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : preCambrian
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and reservoir foundation: Tertiary sediments, schist and granite (age and structure not obtained).
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : preCambrian
NOTES ON FAULTING : Two faults lie within 2 km and 7 km of the dam.
DATE OF FIRST SUSPECTED RIS EVENT : 15-Jul-1931
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 5.75 (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 20-Jul-1938
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Seismicity began as water level reached maximum. Most earthquakes during subsequent reservoir history not clearly correlative with water level fluctuations. Exceptions: in 1951, an earthquake swarm occurred as lake level rose rapidly; microearthquake activity reported to have varied with variation in water level between 1958 and 1966.
GENERAL NOTES : Data reliability is moderate. Weak influence of reservoir on seismicity.
RIS CATEGORY : Accepted () (weak case)
TYPE OF RIS : macro
GEOLOGY REFERENCES : 64,84,106,160,201,203,331

Mattmark

DAM NAME : Mattmark
COUNTRY : Switzerland
RIVER : Saaser Visp
LOCATION OF CENTER OF RESERVOIR : 46.04N, 7.96E
LOCATION OF DAM : 46.06N, 7.96E
PROVINCE OR REGION : Wallis
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1967
NOTES ON HISTORY OF IMPOUNDMENT : Range in filling: as great as 90 m in 4 months during spring floods in 1969
DATE OF START OF FILLING : Impoundment began March 1965
RATE OF INITIAL FILLING : 1.70 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 4.00 (years) years filling
MAXIMUM RATE OF FILLING : 23.00 (m/month) m/month
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : At least 70 m fluctation annually since 1969; Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 120. (m) above lowest foundation
LENGTH OF DAM : 770. m
MAXIMUM DEPTH OF RESERVOIR : 97.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 97.00 m
MAXIMUM VOLUME OF RESERVOIR : 100. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 3.0 km
NOTES ON REGIONAL GEOLOGY : Monte Rosa nappe
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Paleozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Lateral morraines of Allalin Glacier, over- burden as much as 100 m thick, terminal morraine and alluvial sediments, Monte Rosa nappe. Foliation or layering N60E, 40NW
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Mesozoic
ORIENTATION OF STRUCTURAL GRAIN : N60E
DEGREE OF DEFORMATION : Steeply dipping
NOTES ON FAULTING : Nearest fault joins 150 km long right-lateral fault; age of faulting unknown
DISTANCE TO CLOSEST KNOWN FAULT : 17.0 (km) km
GEOLOGY REFERENCES : 63, 106, 178

Mauvoisin

DAM NAME : Mauvoisin
RESERVOIR NAME : Lac de Mauvoisin
COUNTRY : Switzerland
RIVER : Drance de Bagnes
LOCATION OF CENTER OF RESERVOIR : 45.98N, 7.37E
LOCATION OF DAM : 46.00N, 7.36E
PROVINCE OR REGION : Valais
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 237. m
LENGTH OF DAM : 520. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 207.00 m
MAXIMUM VOLUME OF RESERVOIR : 180. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.8 km
NOTES ON REGIONAL GEOLOGY : Schist of Pennine nappe with thrust under crystalline metamorphhics of the Dt. Blanche nappe.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Mesozoic (Jurassic-Cretaceous) schist of Pennine nappe with window of crystalline metamorphics of St. Barnard nappe.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Jurassic
DEGREE OF DEFORMATION : strongly deformed
NOTES ON FAULTING : Thrust faults located at or near dam and upstream transverse to reservoir; both are intra-nappe faults.
PREDOMINANT FAULT TYPE : Thrust
DISTANCE TO CLOSEST KNOWN FAULT : 30.0 (km) km
GEOLOGY REFERENCES : 106, 434

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Miboro

DAM NAME : Miboro
COUNTRY : Japan
RIVER : Sho
LOCATION OF CENTER OF RESERVOIR : 36.11N,136.92E
LOCATION OF DAM : 36.13N,136.91E
PROVINCE OR REGION : Gifu
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 126 m above ground
ORIENTATION OF RESERVOIR : S30E
STRUCTURAL HEIGHT OF DAM : 131. (m) above foundations
LENGTH OF DAM : 405. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 117.90 m
MAXIMUM VOLUME OF RESERVOIR : 370. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 6.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Altered quartz porphyry and granite porphyry.  Crushed fault zone 40 m wide on right bank.
SITE GEOLOGY : Batholithic
NOTES ON FAULTING : Fault located in right dam foundation
GEOLOGY REFERENCES : 106,347,468A
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Mica

DAM NAME : Mica
RESERVOIR NAME : McNaughton Lake
COUNTRY : Canada
RIVER : Columbia
LOCATION OF CENTER OF RESERVOIR : 52.07N, 118.30W
LOCATION OF DAM : 52.10N, 118.57W
PROVINCE OR REGION : British Columbia
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Reservoir has short NE arm into Rocky Mt. Trench, then long NW and SE arms
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 242. m
LENGTH OF DAM : 1068. m
MAXIMUM DEPTH OF RESERVOIR : 191.0 (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 191.00 m
MAXIMUM VOLUME OF RESERVOIR : 31300. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 200.0 km
NOTES ON REGIONAL GEOLOGY : Precambrian to Paleozoic metamorphics
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Precambrian
TECTONIC PROVINCE : Rocky Mountain Trench
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Precambrian mica schist, granitic gneiss, pegmatite, white marble; isoclinal folds with bedding and foliation dipping southward about 20 degrees at dam. 27 m of alluvium, 18 m max. glacial till; fractures as deep as 61 m. Numerous minor faults and joints, most faults filled with brittle, hard gouge less than 1.5 cm thick
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Precambrian
PREDOMINANT FAULT TYPE : Reverse
DIP OF PREDOMINANT FAULTING : NE () dip
NOTES ON HYDROLOGY : Coefficient of permeability ranges from 2.0E-4 cm/sec near the surface to 2.0E-5 cm/sec at a depth of approximately 75 m.
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No change in level of macroseismicity or microseismicity subsequent to reservoir impoundment. Possible but unclear spatial association of seismicity to reservoir.
GENERAL NOTES : Data reliablility is low. Few pre-impoundment data obtained. Seismicity not significantly changed after impoundment.
RIS CATEGORY : Not RIS
GEOLOGY REFERENCES : 108, 127A, 139, 140, 141, 183, 252, 256, 257, 312

Mingechaur

DAM NAME : Mingechaur
RESERVOIR NAME : Mingechaurskoye Vdkhr.
COUNTRY : USSR
RIVER : Kura
LOCATION OF CENTER OF RESERVOIR : 40.83N, 46.83E
PROVINCE OR REGION : Transcaucasus
DAM TYPE : Earth
DATE DAM COMPLETED : 1953
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 80. m
LENGTH OF DAM : 1550. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 76.00 m
MAXIMUM VOLUME OF RESERVOIR : 16000. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 56.0 km
NOTES ON REGIONAL GEOLOGY : Kura depression, southern edge of Caucasus Mts. Region of foredeeps and intermontane downwarps developed during Neogene, near Quaternary intermontane downwarp
TECTONIC PROVINCE : Caucasus
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON FAULTING : Overthrust through axis of reservoir
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : NW () trending
NAME OF CLOSEST KNOWN FAULT : Khodzhasken-Geokchai overthrust
GEOLOGY REFERENCES : 106,302A

Moiry

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DAM NAME : Moiry
COUNTRY : Switzerland
RIVER : Gougra
LOCATION OF CENTER OF RESERVOIR : 46.13N,7.57E
LOCATION OF DAM : 46.14N,7.57E
PROVINCE OR REGION : Valais
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1958
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 148. (m) above lowest foundation
LENGTH OF DAM : 610. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 130.00 m
MAXIMUM VOLUME OF RESERVOIR : 78. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.0 km
NOTES ON REGIONAL GEOLOGY : Permo-Carboniferous and Mesozoic metamorphics and crystalline rocks of the Grand St-Bernard nappe, and
Mesozoic schist nappes with ophiolites
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Reservoir:  Jurassic schist and greenstone. Dam:  Permo-Carboniferous gneiss and mica-schist.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Jurassic
DISTANCE TO CLOSEST KNOWN FAULT : 20.0 (km) km
GEOLOGY REFERENCES : 106,440A,440B
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Monteynard

DAM NAME : Monteynard
RESERVOIR NAME : Lake Monteynard
COUNTRY : France
RIVER : Drac
LOCATION OF CENTER OF RESERVOIR : 44.90N, 5.70E
LOCATION OF DAM : 44.96N, 5.68E
PROVINCE OR REGION : Isere
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1962
DATE OF START OF FILLING : Apr-1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 135 m above ground
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 155. m
LENGTH OF DAM : 215. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 125.00 m
MAXIMUM VOLUME OF RESERVOIR : 275. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 9.0 km
NOTES ON REGIONAL GEOLOGY : Tectonically disturbed area. The Drac Gorge is highly faulted and fractured. East-dipping sediments overlying metamorphics east of dam area.
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Lias limestone that dips 45 deg and is faulted and fissured
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Jurassic
NOTES ON FAULTING : Faults include the north-trending De la Mure fault and numerous east-trending faults. Age and sense of fault displacement unknown.
PREDOMINANT FRACTURE ORIENTATION : N to S (); vertical fractures
DATE OF FIRST SUSPECTED RIS EVENT : 25-Apr-1963
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Int VII (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 25-Apr-1963
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Clear temporal and spatial correlation of seismicity to reservoir. First period of seismic activity, in 1963, occurred when reservoir water level was at maximum. Other seismicity not clearly associated with water level changes.
GENERAL NOTES : Data reliability is low to moderate.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 64,106,201,203,331,393

Mornos

DAM NAME : Mornos
COUNTRY : Greece
RIVER : Mornos
PROVINCE OR REGION : Phocic
DAM TYPE : earth () fill
DATE DAM COMPLETED : 1977
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply
NOTES ON DAM : Cross-shaped reservoir
ORIENTATION OF RESERVOIR : N50E
STRUCTURAL HEIGHT OF DAM : 130. m
LENGTH OF DAM : 815. m
MAXIMUM DEPTH OF RESERVOIR : approximately 123.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 123.00 m
MAXIMUM VOLUME OF RESERVOIR : 780. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 17.0 km
NOTES ON REGIONAL GEOLOGY : Reservoir situated within Olonos-Pindos and Vardousia zones, comprised respectively of flysch deposits and limestone.
REGIONAL GEOLOGY : coarse clastic
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics (), focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : The dam site and reservoir consist of flysch deposits -- siltstone and fine-to-medium-grained sandstone -- with limestone in upper thrust plate in portions of reservoir area. Numerous small faults in reservoir area.
SITE GEOLOGY : Coarse clastic
NOTES ON HYDROLOGY : Flysch deposits have low permeability; however, karstified limestone outcrops in vicinity of reservoir, where it has been thrust over the flysch deposits.
PERMEABILITY OF ROCKS : low () to high
TYPE OF PERMEABILITY : intergranular () to cavernous
DEGREE OF TOPOGRAPHIC RELIEF : high
GEOLOGY REFERENCES : 306,403

Morrow Point

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DAM NAME : Morrow Point
RESERVOIR NAME : Morrow Point
COUNTRY : USA
RIVER : Gunnison
LOCATION OF CENTER OF RESERVOIR : 38.45N,107.45W
PROVINCE OR REGION : Colorado
DAM TYPE : Concrete arch (), variable center
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : No fluctuations; downstream from Blue Mesa. Hydropower ().
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 143. m
LENGTH OF DAM : 226. m
MAXIMUM DEPTH OF RESERVOIR : 122.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 122.00 m
MAXIMUM VOLUME OF RESERVOIR : 144. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 15.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Schist, gneiss, granite -- preCambrian
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Precambrian
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N65W
DIP OF PREDOMINANT FAULTING : NE
MAXIMUM LENGTH OF FAULTS : 13.00 (km) km without Neogene displacement
DOMINANT SIDE UP : S (); south
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Downthrown block
NAME OF CLOSEST KNOWN FAULT : Cimarron fault
DISTANCE TO CLOSEST KNOWN FAULT : 10.0 (km) km south of reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Offsets Miocene unit
GEOLOGY REFERENCES : 106,258
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Mossyrock

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DAM NAME : Mossyrock
RESERVOIR NAME : Lake Davisson
COUNTRY : USA
RIVER : Cowlitz
LOCATION OF CENTER OF RESERVOIR : 46.50N,122.33W
LOCATION OF DAM : 46.53N,122.43W
PROVINCE OR REGION : Washington
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 128 m above ground
STRUCTURAL HEIGHT OF DAM : 184. m
LENGTH OF DAM : 533. m
MAXIMUM DEPTH OF RESERVOIR : 124.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 124.00 m
MAXIMUM VOLUME OF RESERVOIR : 1957. m3x10E6
SURFACE AREA OF RESERVOIR : 46.00 km2
LONGEST DIMENSION OF RESERVOIR : 38.0 km
NOTES ON REGIONAL GEOLOGY : Mt. Rainier region; thick sequence of Eocene (?) lava flows with interbedded flow breccias and
agglomerates.  Broad anticlines and synclines striking more or less north-south and plunging southward.  Pleistocene valley glaciers
originating on Rainier left extensive till and glacio-fluvial deposits
REGIONAL GEOLOGY : Volcanic
AGE OF REGIONAL GEOLOGY : Eocene
TECTONIC PROVINCE : Cascades
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Massive andesite and basalt flows covered by glacial drift (in excess of 70 m thick at dam site). NW and NE
joints at dam, part of regional tectonic system
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Eocene
DEGREE OF DEFORMATION : Shallow dipping
GEOLOGY REFERENCES : 106,147,259A
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Mratinje

DAM NAME : Mratinje
COUNTRY : Yugoslavia
RIVER : Piva
PROVINCE OR REGION : Montenegro
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1976
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 220. m
LENGTH OF DAM : 268. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 190.00 m
MAXIMUM VOLUME OF RESERVOIR : 880. m3x10E6
NOTES ON REGIONAL GEOLOGY : Dinaride Mts. Mesozoic limestone; joints and fissures in dam and reservoir area.
REGIONAL GEOLOGY : Carbonate
AGE OF REGIONAL GEOLOGY : Mesozoic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Mesozoic limestone, karst topography
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Mesozoic
NOTES ON HYDROLOGY : Karst topography
GEOLOGY REFERENCES : 306,385

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Mud Mountain


DAM NAME : Mud Mountain
RESERVOIR NAME : Lake Stevens
COUNTRY : USA
RIVER : White
LOCATION OF CENTER OF RESERVOIR : 47.15N,121.87W
LOCATION OF DAM : 47.15N,121.93W
PROVINCE OR REGION : Washington
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1948
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
NOTES ON DAM : Dam height of 130 m above ground
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 130. m
LENGTH OF DAM : 213. m
MAXIMUM DEPTH OF RESERVOIR : 107.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 107.00 m
MAXIMUM VOLUME OF RESERVOIR : 131. m3x10E6
SURFACE AREA OF RESERVOIR : 4.60 km2
LONGEST DIMENSION OF RESERVOIR : 8.8 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Tuff and andesite conglomerates, fissured quartzite
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Tertiary
GEOLOGY REFERENCES : 106,289
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Mula

DAM NAME : Mula
RESERVOIR NAME : Mula
COUNTRY : India
RIVER : Mula
LOCATION OF CENTER OF RESERVOIR : 19.37N, 74.62E
LOCATION OF DAM : 19.37N, 74.62E
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1972
DATE OF START OF FILLING : 1-Jul-1972
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 56. m
LENGTH OF DAM : 2819. m
MAXIMUM DEPTH OF RESERVOIR : 44.0 (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 44.00 (m) m
MAXIMUM VOLUME OF RESERVOIR : 1017. m3x10E6
NOTES ON REGIONAL GEOLOGY : Peninsular Shield of India; stable region with relatively low seismicity.
REGIONAL GEOLOGY : Volcanic
AGE OF REGIONAL GEOLOGY : Tertiary
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and Reservoir Foundation: Deccan Trap deposits of Late Cretaceous to Eocene age. Bedding near horizontal. River bed and banks up to 3 km on either side are covered by as much as 40 m of alluvium (sand, silt, and gravel), in part cemented with calcium carbonate. Reservoir underlain by similar units.
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Tertiary (Eocene?)
NOTES ON FAULTING : Deccan Trap typically is unfaulted, but has extensive fractures. A major fracture, present upstream from the dam, is approximately 400 m long and 1 to 5 cm wide.
NOTES ON HYDROLOGY : Estimated moderate to high permeability in basalt flows and alluvium, respectively. Probable high groundwater table.
PERMEABILITY OF ROCKS : medium
DEGREE OF TOPOGRAPHIC RELIEF : low
DATE OF FIRST SUSPECTED RIS EVENT : 1-Sep-1972
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Two months after reservoir impoundment began, reservoir attained maximum level at which time microearthquake activity increased significantly. Subsequently reservoir levels declined and microearthquake frequency returned to near pre-impoundment levels. This correlation is reported to have been repeated in the 3 following years.
GENERAL NOTES : Data reliability is moderate to good. Definite increase in micro-earthquake activity when reservoir attained maximum level. No event of magnitude larger than 1. Date are sparse. No locations of events. No macroseismicity located near dam by ISC.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 13, 107, 188, 190, 195, 196, 203

Nagarjunasagar

DAM NAME : Nagarjunasagar
RESERVOIR NAME : Nagarjunasagar
COUNTRY : India
RIVER : Krishna
LOCATION OF CENTER OF RESERVOIR : 16.46N, 79.20E
LOCATION OF DAM : 16.60N, 79.31E
PROVINCE OR REGION : Andhra Pradesh
DAM TYPE : Gravity
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 125. m
MAXIMUM DEPTH OF RESERVOIR : 114.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 114.00 m
MAXIMUM VOLUME OF RESERVOIR : 11558. m3x10E6
SURFACE AREA OF RESERVOIR : 280.00 km2
NOTES ON REGIONAL GEOLOGY : Granite with gneiss of Peninsular complex. Includes quartzite and shale of Cuddapah series.
REGIONAL GEOLOGY : Metamorphic
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Granite underlying 3 m alluvium. Flanks of dam site consist of flat-bedded quartzites and shales, overlying granite with thickness of 27 to 44 m. 1.2 to 4.9 m wide crushed fault zone in granite; additional 0.7 to 1.4 m wide crushed zone in foundation.
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 107,323

Nagawado

DAM NAME : Nagawado
COUNTRY : Japan
RIVER : Azusa
LOCATION OF CENTER OF RESERVOIR : 36.14N, 137.71E
PROVINCE OR REGION : Nagano
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1969
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 155. (m) above lowest foundations
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 125.00 m
MAXIMUM VOLUME OF RESERVOIR : 123. m3x10E6
SURFACE AREA OF RESERVOIR : 2.74 km2
LONGEST DIMENSION OF RESERVOIR : 6.0 km
NOTES ON REGIONAL GEOLOGY : Primarily alternating clayslate, sandstone, and chert, NE strike
REGIONAL GEOLOGY : Metamorphic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Granite and hornfels at top of dam site. Almost vertical fractures or faults in granite. Dominant joint pattern at dam N83W, 78N. Lamprophyre dike present in foundation.
SITE GEOLOGY : Metamorphic
PREDOMINANT FRACTURE ORIENTATION : N83W
GEOLOGY REFERENCES : 28, 107, 157, 233, 314, 316

Nalps

DAM NAME : Nalps
COUNTRY : Switzerland
RIVER : Rein de Nalps
LOCATION OF CENTER OF RESERVOIR : 46.63N, 8.80E
PROVINCE OR REGION : Grischun
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 128. (m) above lowest foundation
LENGTH OF DAM : 480. m
MAXIMUM DEPTH OF RESERVOIR : 110.0 (m) (calculated from topographic map)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 110.00 m
MAXIMUM VOLUME OF RESERVOIR : 45. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 2.0 (km) (from topo map)
NOTES ON REGIONAL GEOLOGY : Paleozoic St. Gothard massif
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Paleozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Permo-Carboniferous gneiss and micaschist
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Permian
MAXIMUM LENGTH OF FAULTS : 80.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : 8.0 (km) km
DISTANCE FROM DAM TO NEAREST EARTHQUAKE BEFORE FILLING : no value
GEOLOGY REFERENCES : 106, 440A, 440B

Nanakura

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DAM NAME : Nanakura
COUNTRY : Japan
RIVER : Takase
DAM TYPE : Earth
DATE DAM COMPLETED : 1978
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 125. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.50 m
MAXIMUM VOLUME OF RESERVOIR : 16. m3x10E6
SURFACE AREA OF RESERVOIR : 0.72 km2
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Jurassic porphyritic granite; 10 to 30 m thick alluvial terrace and Recent alluvium 10 m thick
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Jurassic
GEOLOGY REFERENCES : 108,313,315
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Navajo

DAM NAME : Navajo
RESERVOIR NAME : Navajo
COUNTRY : USA
RIVER : San Juan
LOCATION OF CENTER OF RESERVOIR : 36.92N,107.50W
PROVINCE OR REGION : New Mexico
DAM TYPE : Earth
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation () and flood control
NOTES ON DAM : Dam height of 118 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 112. m
LENGTH OF DAM : 1112. m
MAXIMUM DEPTH OF RESERVOIR : 118.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 118.00 m
MAXIMUM VOLUME OF RESERVOIR : 2108. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 34.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Horizontal bedded sandstone
SITE GEOLOGY : Coarse clastic
DEGREE OF DEFORMATION : Flatlying
GEOLOGY REFERENCES : 106
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New Bullards Bar

DAM NAME : New Bullards Bar
RESERVOIR NAME : New Bullards Bar
COUNTRY : USA
RIVER : North Fork Yuba
LOCATION OF CENTER OF RESERVOIR : 39.43N, 121.10W
LOCATION OF DAM : 39.39N, 121.10W
PROVINCE OR REGION : California
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1970
NOTES ON HISTORY OF IMPOUNDMENT : Filling began in August 1968. Between Dec. 1969 and Jan. 1970 33 percent volume filling in one month. Seasonal fluctuations as great as 60% of volume.
DATE OF START OF FILLING : Aug-1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (), multi-purpose
NOTES ON DAM : Y-shaped reservoirs with arms N and NE from center of reservoir. Dam 187 m above ground level.
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 194. m
LENGTH OF DAM : 671. m
MAXIMUM DEPTH OF RESERVOIR : 174.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 174.00 m
MAXIMUM VOLUME OF RESERVOIR : 1184. m3x10E6
SURFACE AREA OF RESERVOIR : 19.40 km2
LONGEST DIMENSION OF RESERVOIR : 8.4 km
NOTES ON REGIONAL GEOLOGY : Mesozoic metavolcanic and granitic rocks; reservoir region includes Foothills fault and ophiolites of the Smartville block, granodiorite of the complex Sierran batholith, and Paleozoic pre-Sierran metamorphic melange.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Sierra Nevada
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Reservoir underlain principally by Cretaceous granodiorite. Dam underlain by metavolcanics; extension of Bear Mountains fault zone through southern arm of reservoir.
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Cretaceous
ORIENTATION OF STRUCTURAL GRAIN : NW
NOTES ON FAULTING : Extension of Bear Mountains fault passes through reservoir; here it separates Mesozoic ophiolitic complex from plutonic complex. No evidence of late Cenozoic faulting within reservoir area.
AZIMUTH OF PREDOMINANT FAULTING : N20W
MAXIMUM LENGTH OF FAULTS : 80.00 (km) km
PERMEABILITY OF ROCKS : low
TYPE OF PERMEABILITY : fracture
DEGREE OF TOPOGRAPHIC RELIEF : Moderate
GEOLOGY REFERENCES : Woodward-Clyde; 107, 235

## New Don Pedro

DAM NAME : New Don Pedro
RESERVOIR NAME : Don Pedro Reservoir
COUNTRY : USA
RIVER : Tuolumne
LOCATION OF CENTER OF RESERVOIR : 37.73N, 120.33W
LOCATION OF DAM : 37.67N, 120.40W
PROVINCE OR REGION : California
DAM TYPE : Earth () and rock fill
DATE DAM COMPLETED : 1971
NOTES ON HISTORY OF IMPOUNDMENT : Filling was slow; reservoir was filled by June 1973 to 60 percent volume.
DATE OF START OF FILLING : Nov-1970
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () and flood control are principal uses.
NOTES ON DAM : L-shaped reservoir trends northeast from dam then long arm northwest, for net NE direction.
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 178. m
LENGTH OF DAM : 579. m
MAXIMUM DEPTH OF RESERVOIR : 156.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 156.00 m
MAXIMUM VOLUME OF RESERVOIR : 2504. m3x10E6
SURFACE AREA OF RESERVOIR : 52.50 km2
LONGEST DIMENSION OF RESERVOIR : 13.2 km
NOTES ON REGIONAL GEOLOGY : Mesozoic metavolcanics, slate, and ultrabasics of Western and Mother Lode belts of the Sierran foothills with minor intrusives of Sierran batholith.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Sierran Foothills
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Jurassic metavolcanics, granitic rocks, and ultrabasics.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Jurassic
ORIENTATION OF STRUCTURAL GRAIN : NW
NOTES ON FAULTING : Bear Mountains fault zone traverses reservoir area. Total zone length 150 km. Although Mesozoic displacement on these faults was high-angle reverse, late Cenozoic displacement, where documented, has been east-side-down normal in this tectonic environment.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N30W
DOMINANT SIDE UP : E (); east
NAME OF CLOSEST KNOWN FAULT : Don Pedro Reservoir fault, Fortynine fault, and other faults and shear zones.
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; within reservoir
GEOLOGY REFERENCES : Woodward-Clyde, 107, 235

New Exchequer

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DAM NAME : New Exchequer
RESERVOIR NAME : Lake McClure
COUNTRY : USA
RIVER : Merced
LOCATION OF CENTER OF RESERVOIR : 37.62N,120.27W
PROVINCE OR REGION : California
DAM TYPE : Rock () fill, concrete face
DATE DAM COMPLETED : 1966
NOTES ON HISTORY OF IMPOUNDMENT : 70 percent volume increase in 11 months
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose. Irrigation () is primary purpose; seasonal volume increase 60 percent in
5 months, maximum drawdown 40 percent in 3 months
NOTES ON DAM : Dam height of 146 m above ground, L-shaped reservoir.
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 149. m
LENGTH OF DAM : 378. m
MAXIMUM DEPTH OF RESERVOIR : 131.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 131.00 m
MAXIMUM VOLUME OF RESERVOIR : 1266. m3x10E6
SURFACE AREA OF RESERVOIR : 29.00 km2
LONGEST DIMENSION OF RESERVOIR : 17.0 km
TECTONIC PROVINCE : Sierran foothills
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Mesozoic metavolcanics, slate, and meta conglomerate.  Ultrabasic intrusives.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Mesozoic
NOTES ON FAULTING : Mesozoic subduction - related reverse faults of Bear Mountains fault zone exhibit late Cenozoic normal
displacement, at least locally.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N20W to N25W
MAXIMUM LENGTH OF FAULTS : 150.00 (km) km (Bear Mountain fault zone); 15 km shear zone intersects reservoir
DOMINANT SIDE UP : W (); west
NAME OF CLOSEST KNOWN FAULT : Bear Mountains fault zone
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km (through reservoir)
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Pre-late Cenozoic (Mesozoic) Late Cenozoic displacement on some strands of
Bear Mountain fault zone
PERMEABILITY OF ROCKS : 60 to 180 m/yr transmissibility; low
TYPE OF PERMEABILITY : Fracture (); joints, foliation, shears
GEOLOGY REFERENCES : Woodward-Clyde,106,235
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Nezahualcoyotl

DAM NAME : Nezahualcoyotl
RESERVOIR NAME : Nezahualcoyotl
COUNTRY : Mexico
RIVER : Grijalva
LOCATION OF CENTER OF RESERVOIR : 17.17N, 93.67W
LOCATION OF DAM : 17.18N, 93.40W
PROVINCE OR REGION : Chiapas
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply
NOTES ON DAM : Arms E and W from dam; dam height of 114 m above ground.
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 130. m
LENGTH OF DAM : 2065. m
MAXIMUM DEPTH OF RESERVOIR : 103.0 (m) m (from drawing)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 103.00 m
MAXIMUM VOLUME OF RESERVOIR : 12500. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 53.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Conglomerate, sandstone, and some shale at dam, Oligocene and Eocene shales in most of reservoir.
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Eocene
GEOLOGY REFERENCES : 106

Nuraghe Arrubiu

DAM NAME : Nuraghe Arrubiu
COUNTRY : Italy
RIVER : Flumendosa
PROVINCE OR REGION : Sardinia
DAM TYPE : Concrete arch () gravity
DATE DAM COMPLETED : 1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; first use is Irrigation
NOTES ON DAM : Dam height of 112 m above ground
STRUCTURAL HEIGHT OF DAM : 119. m
LENGTH OF DAM : 295. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 101.00 m
MAXIMUM VOLUME OF RESERVOIR : 312. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Porphyry
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106

Nurek

DAM NAME : Nurek
RESERVOIR NAME : Nurek
COUNTRY : USSR
RIVER : Vakhsh
LOCATION OF DAM : 38.42N,69.27E
PROVINCE OR REGION : Tadzhikskaya
DAM TYPE : earth () fill
DATE DAM COMPLETED : scheduled 1979
DATE OF START OF FILLING : Sep-1972
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (), Irrigation
NOTES ON DAM : Dam under construction in phases; first phase completed 1967. Scheduled completion of entire project is 1985, with dam completion in 1979.
STRUCTURAL HEIGHT OF DAM : 317. (m) above lowest foundation
LENGTH OF DAM : 729. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 285.30 m
MAXIMUM VOLUME OF RESERVOIR : 11000. m3x10E6
SURFACE AREA OF RESERVOIR : 74.00 km2
NOTES ON REGIONAL GEOLOGY : Tectonically active Tadjikistan depression contains northeast-trending active thrust faults.
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics (), focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Mesozoic and Cenozoic marine and platform sedimentary rock, with Neogene and Quaternary molasse with gypsum-salt series.
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Mesozoic
NOTES ON FAULTING : Northeast-trending thrust faults, one of which is active, pass on either side of the reservoir. Other active thrust faults are present in the region. Dam and reservoir are in a structural graben.
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : NE
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; side of reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary
ARE LOCAL FAULTS ACTIVE? : Yes
SEISMICITY ASSOCIATED WITH FAULTS IN LOCAL AREA? : Yes (), downstream from dam
NOTES ON HYDROLOGY : Possible moderate permeability in clastic sedimentary formations, which would result in low groundwater gradient in reservoir banks prior to impoundment.
PERMEABILITY OF ROCKS : medium
TYPE OF PERMEABILITY : intergranular () and fracture
GROUNDWATER GRADIENT : low
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : 6-Nov-1972
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.5
DATE OF LARGEST SUSPECTED RIS EVENT : 27-Nov-1972
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Increases and decreases in seismic activity correlate (with virtually no delay time) with fluctuations in water level over the 3 years for which post-impoundment data are available.
GENERAL NOTES : Area of high seismicity with many large local earthquakes prior to, and after filling.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 60,203,206,418,418A,432

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O'Shaughnessy


DAM NAME : O'Shaughnessy
RESERVOIR NAME : Hetch-Hetchy
COUNTRY : USA
RIVER : Tuolumne
PROVINCE OR REGION : California
DAM TYPE : Gravity
DATE DAM COMPLETED : 1938
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply (), hydropower, irrigation
NOTES ON DAM : Dam height of 95 m above ground
STRUCTURAL HEIGHT OF DAM : 131. m
LENGTH OF DAM : 277. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 113.00 m
MAXIMUM VOLUME OF RESERVOIR : 516. m3x10E6
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 107
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Oahe


DAM NAME : Oahe
RESERVOIR NAME : Lake Oahe
COUNTRY : USA
RIVER : Missouri
LOCATION OF CENTER OF RESERVOIR : 45.50N,100.42W
LOCATION OF DAM : 44.35N,100.38W
PROVINCE OR REGION : South Dakota/North Dakota
DAM TYPE : Earth
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : multi-purpose; Flood control () is principal use.
NOTES ON DAM : Dam height of 75 m above ground
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 75. m
LENGTH OF DAM : 2835. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 71.25 m
MAXIMUM VOLUME OF RESERVOIR : 29110. m3x10E6
SURFACE AREA OF RESERVOIR : 1782.00 km2
LONGEST DIMENSION OF RESERVOIR : 245.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOIES ON SITE GEOLOGY : Shale and glacial deposits
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Cretaceous
GEOLOGY REFERENCES : 106,306,468B
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Ogochi

DAM NAME : Ogochi
RESERVOIR NAME : Okutama-Ko
COUNTRY : Japan
RIVER : Tama
LOCATION OF CENTER OF RESERVOIR : 35.78N,139.03E
LOCATION OF DAM : 35.78N,139.07E
PROVINCE OR REGION : Tokyo
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply () and hydropower
NOTES ON DAM : Dam height of 146 m above ground
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 149. m
LENGTH OF DAM : 353. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 131.00 m
MAXIMUM VOLUME OF RESERVOIR : 189. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 5.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Greywacke, shale
SITE GEOLOGY : Coarse clastic
GEOLOGY REFERENCES : 106,289,468A

**Okutadami**

DAM NAME : Okutadami
COUNTRY : Japan
RIVER : Tadami
LOCATION OF CENTER OF RESERVOIR : 37.13N,139.24E
LOCATION OF DAM : 37.15N,139.25E
PROVINCE OR REGION : Niigata
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 153 m above ground
ORIENTATION OF RESERVOIR : S25W
STRUCTURAL HEIGHT OF DAM : 157. m
LENGTH OF DAM : 480. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 127.00 m
MAXIMUM VOLUME OF RESERVOIR : 601. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Shale
SITE GEOLOGY : Fine clastic
GEOLOGY REFERENCES : 106,289

Oroville

DAM NAME : Oroville
RESERVOIR NAME : Lake Oroville
COUNTRY : USA
RIVER : Feather
LOCATION OF CENTER OF RESERVOIR : 39.53N,121.43W
LOCATION OF DAM : 39.53N,121.50W
PROVINCE OR REGION : California
DAM TYPE : Zoned earth () fill
DATE DAM COMPLETED : 1968
NOTES ON HISTORY OF IMPOUNDMENT : November 1967 to April 1968, 0-1850E06 cubic m; 45% full in 6 months (slow). Final filling of 50% capacity in 2 1/2 months. Filled to capacity in Jan. 1969. Lowest drawdowns in early 1975 and 1977; refilled to capacity in July 1975. Maximum of 60% fluctuations from Feb. to June 1975, drawdown July to Dec. 1974.
DATE OF START OF FILLING : 1-Nov-1967
RATE OF INITIAL FILLING : 10.00 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 1.60 (years) years
MAXIMUM RATE OF FILLING : 26.00 (m/month) m/month in 1968 during initial filling
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (). Maximum pre-drought fluctuation of 60% of capacity, 1974.
ORIENTATION OF RESERVOIR : N (); arms NE and E
STRUCTURAL HEIGHT OF DAM : 236. m
LENGTH OF DAM : 2073. m
MAXIMUM DEPTH OF RESERVOIR : 204.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 204.00 m
MAXIMUM VOLUME OF RESERVOIR : 4400. m3x10E6
SURFACE AREA OF RESERVOIR : 63.00 km2
LONGEST DIMENSION OF RESERVOIR : 30.0 km
NOTES ON REGIONAL GEOLOGY : Western metamorphic belt of the Sierra Nevada. Extensional tectonic stress regime.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Jurassic
TECTONIC PROVINCE : Sierra Nevada block
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Mesozoic metavolcanic rock of amphibolite with granitic units. Some foliation is oriented N12W,77NE. Joint sets result in the metavolcanic units being somewhat blocky.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Jurassic
DEGREE OF DEFORMATION : Foliated, fractured, steeply dipping ().
NOTES ON FAULTING : Talc zones and schistose zones, steeply dipping, occur in dam area. Late Cenozoic normal faulting exists within the Foothills fault system about 2 km west of the dam. 1975 surface fault ruptures within 10 km of reservoir.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N25W to N10E
DIP OF PREDOMINANT FAULTING : E (); east
MAXIMUM LENGTH OF FAULTS : 14.00 (km) km; 5 km surface rupture, 1975
DOMINANT SIDE UP : W (); west
PREDOMINANT FRACTURE ORIENTATION : N to N30W
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Downthrown block
NAME OF CLOSEST KNOWN FAULT : Cleveland Hills fault
DISTANCE TO CLOSEST KNOWN FAULT : 10.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Historic (1 Aug 1975)
ARE LOCAL FAULTS ACTIVE? : Yes
SEISMICITY ASSOCIATED WITH FAULTS IN LOCAL AREA? : Yes

NOTES ON HYDROLOGY : Steep v-shaped valleys, local relief of 50 m. Incised drainages. Permeability of rocks generally low; locally 0 25-0.56 gpd/sq. ft.
PERMEABILITY OF ROCKS : Low
TYPE OF PERMEABILITY : Fracture ()s, joints, shears, schistose zones
GROUNDWATER GRADIENT : Medium (); 0.09-0.20 liter per day per sq. m
DEGREE OF TOPOGRAPHIC RELIEF : Moderate () to high
DATE OF FIRST SUSPECTED RIS EVENT : 28-Jun-1975
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 5.7
DATE OF LARGEST SUSPECTED RIS EVENT : 1-Aug-1975
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No activity occurred for 8 years subsequent to impoundment. Foreshocks of the maximum event occurred shortly after water level had been drawn down to lowest elevation in 6 years. Maximum event occurred as the reservoir level was raised to maximum level previously attained. It occurred 11 km southwest of the dam at a focal depth of 5.5 to 8 km. The aftershocks occurred in a 130-sq-km area centered about 8 km from the dam; the focal depths of the aftershocks varied from at the surface to a depth of 10 km.
GENERAL NOTES : Data reliability is moderate.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 42, 72, 106, 121, 216, 222, 235, 268A, 272, 320, 399, 400, 418, Woodward-Clyde Consultants work

Oued Fodda

DAM NAME : Oued Fodda
RESERVOIR NAME : Oued Fodda
COUNTRY : Algeria
RIVER : Oued Fodda
LOCATION OF CENTER OF RESERVOIR : 36.02N, 1.60E
LOCATION OF DAM : 36.05N, 1.61E
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1933
NOTES ON HISTORY OF IMPOUNDMENT : Reservoir capacity reduced 50 percent between 1942 and 1962 due to sediment accumulation.
DATE OF START OF FILLING : Nov-1932
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Dam height of 89 m above stream bed.
ORIENTATION OF RESERVOIR : S30W
STRUCTURAL HEIGHT OF DAM : 101. m
LENGTH OF DAM : 181. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 83.00 m
MAXIMUM VOLUME OF RESERVOIR : 225. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 6.0 (km) km
NOTES ON REGIONAL GEOLOGY : In the Tell Atlas Mountains of northern Africa. Mesozoic carbonate units deformed during Mesozoic-Cenozoic orogenic events. Region of historical compression related to collision of African and Eurasian plates.
REGIONAL GEOLOGY : Carbonate
AGE OF REGIONAL GEOLOGY : Jurassic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON FAULTING : Faults: Limestones are fissured in the dam and reservoir area. No additional data obtained.
DATE OF FIRST SUSPECTED RIS EVENT : Jan-1933
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No change in level of macroseismicity. Microseismicity began within a few months of the start of impoundment, continued for 5 months, then stopped.
GENERAL NOTES : Data reliability is low. Few data were obtained. Region of seismic activity. No base-line data were obtained that describe the location of events.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 64,106,203,289,331,468A

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Outardes #4


DAM NAME : Outardes #4
RESERVOIR NAME : Outardes
COUNTRY : Canada
RIVER : Outardes
LOCATION OF CENTER OF RESERVOIR : 50.13N,69.11W
LOCATION OF DAM : 49.75N,68.89W
PROVINCE OR REGION : Quebec
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1968
NOTES ON HISTORY OF IMPOUNDMENT : Begun in April 1968, 1st peak December 1969, fluctuations no more than 8 m to 1975
DATE OF START OF FILLING : Apr-1968
YEARS FROM BEGINNING TO MAXIMUM FILL : 1.70 (years) years
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (); maximum fluctuation 8 m
ORIENTATION OF RESERVOIR : N15W
STRUCTURAL HEIGHT OF DAM : 134. (m) above lowest foundation for highest dam
MAXIMUM DEPTH OF RESERVOIR : 116.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 116.00 m
MAXIMUM VOLUME OF RESERVOIR : 2430. m3x10E6
SURFACE AREA OF RESERVOIR : 666.00 km2
LONGEST DIMENSION OF RESERVOIR : 170.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Gabbro and anorthosite, talus 10 m deep on left bank
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 81,106,338
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Owyhee

DAM NAME : Owyhee
RESERVOIR NAME : Lake Owyhee
COUNTRY : USA
RIVER : Owyhee
LOCATION OF CENTER OF RESERVOIR : 43.45N,117.35W
LOCATION OF DAM : 43.64N,117.32W
PROVINCE OR REGION : Oregon
DAM TYPE : Arch
DATE DAM COMPLETED : 1932
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation () and flood control
NOTES ON DAM : Dam height of 99 m above ground
ORIENTATION OF RESERVOIR : S70W
STRUCTURAL HEIGHT OF DAM : 127. m
LENGTH OF DAM : 254. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 109.00 m
MAXIMUM VOLUME OF RESERVOIR : 1384. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 40.0 (km) km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 107
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**Palisades**

DAM NAME : Palisades
RESERVOIR NAME : Palisades
COUNTRY : USA
RIVER : Snake
LOCATION OF CENTER OF RESERVOIR : 43.23N, 111.12W
LOCATION OF DAM : 43.33N, 111.21W
DAM TYPE : earth () fill
DATE DAM COMPLETED : 1957
DATE OF START OF FILLING : Date of impoundment 1956
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () is first use listed
NOTES ON DAM : Dam height of 76 m above ground
ORIENTATION OF RESERVOIR : S33E
STRUCTURAL HEIGHT OF DAM : 82. m
MAXIMUM DEPTH OF RESERVOIR : 67.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 67.00 m
MAXIMUM VOLUME OF RESERVOIR : 1729. m3x10E6
SURFACE AREA OF RESERVOIR : 108.00 km2
LONGEST DIMENSION OF RESERVOIR : 26.0 (km) km
NOTES ON REGIONAL GEOLOGY : Regional geologic setting: Swan Valley graben between the Snake River Range and Caribou Range, which are underlain by Paleozoic and Cretaceous sedimentary rocks.
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON FAULTING : The Grand Valley fault and a series of parallel faults including the Swan Valley fault are responsible for graben downdrop. Time of most recent displacement was not obtained.
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : 22-Sep-1963
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 3.7 Mb (NOAA)
DATE OF LARGEST SUSPECTED RIS EVENT : 10-Jun-1966
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Post-impoundment microseismicity exhibits correlation with water level changes; however, the spatial association of this seismicity with the reservoir is unclear.
GENERAL NOTES : Influcence of reservoir on seismicity not strongly established. Post-impoundment seismicity may be recognized only because of increased netword coverage.
RIS CATEGORY : Accepted () (weak case)
TYPE OF RIS : micro
GEOLOGY REFERENCES : 79, 106, 203, 289, 404

Paradela

DAM NAME : Paradela
COUNTRY : Portugal
RIVER : Cavado
LOCATION OF CENTER OF RESERVOIR : 41.78N,7.96W
PROVINCE OR REGION : Vila Real
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1958
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 107 m above ground
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 110. m
LENGTH OF DAM : 540. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 99.00 m
MAXIMUM VOLUME OF RESERVOIR : 165. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 0.5 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Highly fissured granite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,289

Parambikulam

DAM NAME : Parambikulam
RESERVOIR NAME : Parambikulam
COUNTRY : India
RIVER : Parambikulam
LOCATION OF CENTER OF RESERVOIR : 10.38N,76.80E
LOCATION OF DAM : 10.37N,76.77E
DAM TYPE : Gravity
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation () and hydropower
NOTES ON DAM : Dam height of 57 m above ground.
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 73. m
LENGTH OF DAM : 318. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 66.00 (m) m
MAXIMUM VOLUME OF RESERVOIR : 504. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 8.0 (km) km
NOTES ON REGIONAL GEOLOGY : Margin of the Peninsular Shield of India.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Archaean
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOIES ON SITE GEOLOGY : Biotite gneiss and charnockite
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Archaean
PREDOMINANT FAULT TYPE : Normal
NAME OF CLOSEST KNOWN FAULT : Palaghat Gap
DISTANCE TO CLOSEST KNOWN FAULT : 4.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Miocene
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No microearthquakes located near reservoir by ISC.
GENERAL NOTES : Insufficient data available to evaluate.
RIS CATEGORY : Questionable
GEOLOGY REFERENCES : 93,106,192,195,203,379

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Pardee


DAM NAME : Pardee
RESERVOIR NAME : Pardee
COUNTRY : USA
RIVER : Mokelumne
LOCATION OF CENTER OF RESERVOIR : 38.27N,120.85W
PROVINCE OR REGION : California
DAM TYPE : Concrete arch () gravity
DATE DAM COMPLETED : 1929
NOTES ON HISTORY OF IMPOUNDMENT : Initial filling included 33 m rise in first 6 months, followed by 33 m drawdown in following 6
months.
DATE OF START OF FILLING : Dec-1929
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : <none>
MAXIMUM DEPTH OF RESERVOIR : 95.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 95.00 m
MAXIMUM VOLUME OF RESERVOIR : 274. m3x10E6
SURFACE AREA OF RESERVOIR : 8.60 km2
LONGEST DIMENSION OF RESERVOIR : 11.0 km
TECTONIC PROVINCE : Sierran foothills
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Mesozoic metavolcaic and ultrabasic rocks, Paleozoic and upper Jurassic marine metasedimentary rocks.
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Jurassic
NOTES ON FAULTING : Mesozoic subduction-related reverse faults reactivated as late Cenozoic normal faults, at least locally.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N20W
DIP OF PREDOMINANT FAULTING : East
MAXIMUM LENGTH OF FAULTS : 150.00 (km) km (Bear Mountains); 5 km (Youngs Creek)
DOMINANT SIDE UP : W (); west
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Bear Mountain zone traverses upper part of reservoir
NAME OF CLOSEST KNOWN FAULT : Youngs Creek
DISTANCE TO CLOSEST KNOWN FAULT : 3.0 (km) km southeast of reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Late Cenozoic (Youngs Creek)
ARE LOCAL FAULTS ACTIVE? : Yes
PERMEABILITY OF ROCKS : Low
TYPE OF PERMEABILITY : Joints, phyllite seams, fracture
DEGREE OF TOPOGRAPHIC RELIEF : moderate
GEOLOGY REFERENCES : 106,121,Woodward-Clyde
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Piastra

DAM NAME : Piastra
RESERVOIR NAME : Lago della Piastra
COUNTRY : Italy
RIVER : Gesso
LOCATION OF CENTER OF RESERVOIR : 44.21N, 7.21E
LOCATION OF DAM : 44.22N, 7.21E
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1965
DATE OF START OF FILLING : Jun-1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 93. (m) m
LENGTH OF DAM : 430. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 83.70 m
MAXIMUM VOLUME OF RESERVOIR : 13. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 2.0 (km) km
NOTES ON REGIONAL GEOLOGY : In the Maritime Alps near the margins of the Pennine Nappes and the Po Valley. Units are Mesozoic and Cenozoic flysch deposits and crystalline massifs. Major NW-trending thrust faults with southwest displacement are present.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON FAULTING : Regional thrust faults trending NW trend through or very near the dam and reservoir area. The Stura fault trends E south of the dam and reservoir.
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : Oct-1965
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.4 (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 7-Apr-1966
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Good spatial and temporal association of seismicity with initial impoundment. Apparent increase in seismic frequency from mid 1965 with a number of earthquakes close to the dam in September 1966.
GENERAL NOTES : Data reliability is low. Few data were obtained. Base-line data not presented.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 64, 102, 106

Pieve di Cadore

DAM NAME : Pieve di Cadore
RESERVOIR NAME : Lago di Pieve di Cadore
COUNTRY : Italy
RIVER : Piave
LOCATION OF CENTER OF RESERVOIR : 46.45N, 12.41E
LOCATION OF DAM : 46.42N, 12.38E
PROVINCE OR REGION : Belluno
DAM TYPE : Concrete arch () gravity
DATE DAM COMPLETED : 1949
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 108 above ground.
ORIENTATION OF RESERVOIR : N35E
STRUCTURAL HEIGHT OF DAM : 116. (m) above found.
LENGTH OF DAM : 410. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 98.00 m
MAXIMUM VOLUME OF RESERVOIR : 69. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 8.6 (km) km
NOTES ON REGIONAL GEOLOGY : In the Dolomite Mountains of the Dinaride section of the southern Alps. Mesozoic carbonate and local flysch deposits with southward thrust faulting along faults oriented primarily east-west.
REGIONAL GEOLOGY : carbonate
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and reservoir foundation: Dam underlain by upper Triassic dolomite. Data on reservoir bedrock not obtained. Fractures present in reservoir area.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : upper Triassic
NOTES ON HYDROLOGY : Inferred low permeability in dolomite except in fracture zones. Topographic development probably too youthful for karstification.
DATE OF FIRST SUSPECTED RIS EVENT : 1950
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Int V
DATE OF LARGEST SUSPECTED RIS EVENT : 13-Jan-1950
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Although no clear spatial association is observed, the level of macroseismicity has increased subsequent to reservoir impoundment. Microseismicity also associated with filling in 1950 and refilling in 1964
GENERAL NOTES : Data reliability is moderate. Pre-impoundment seismicity not obtained. Base-line data not obtained. Apparently an increase in microeqrthquake activity occurred during impoundment.
RIS CATEGORY : Accepted
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 64, 80, 102, 106, 203, 289, 394, 418

Pine Flat

DAM NAME : Pine Flat
RESERVOIR NAME : Pine Flat Lake
COUNTRY : USA
RIVER : Kings
LOCATION OF CENTER OF RESERVOIR : 36.87N, 119.30W
PROVINCE OR REGION : California
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1954
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () first use. Fluctuations are seasonal. Common 50 percent drawdowm in 3- to 4-month period. Rapid 60 percent drawdowns in June through October 1957 and 1973. One week 40 percent filling, January 1969.
NOTES ON DAM : Dam height of 126 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 131. (m) foundation
LENGTH OF DAM : 561. m
MAXIMUM DEPTH OF RESERVOIR : 116.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 116.00 m
MAXIMUM VOLUME OF RESERVOIR : 1233. m3x10E6
SURFACE AREA OF RESERVOIR : 24.00 km2
LONGEST DIMENSION OF RESERVOIR : 15.3 km
NOTES ON REGIONAL GEOLOGY : Pre-Cenozoic granitic and metamorphic rocks. Mesozoic ultrabasic and granitic rocks. Pre-Cretaceous metavolcanics.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Sierran foothills
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Amphibolite
SITE GEOLOGY : Metamorphic
MAXIMUM LENGTH OF FAULTS : 7.00 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : 30 km NW of dam
PERMEABILITY OF ROCKS : Low
TYPE OF PERMEABILITY : Fracture
DEGREE OF TOPOGRAPHIC RELIEF : moderate () to high
GEOLOGY REFERENCES : 106, 121, 289

# Place Moulin

DAM NAME : Place Moulin
RESERVOIR NAME : Lago di Place Moulin
COUNTRY : Italy
RIVER : Buthier
LOCATION OF CENTER OF RESERVOIR : 45.91N, 7.52E
PROVINCE OR REGION : Valle d'Aosta
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (); height of reservoir varied between 1830 m and 1968 m between 1965 and 1969
NOTES ON DAM : Dam height of 140 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 155. (m) above foundation
LENGTH OF DAM : 663. m
MAXIMUM DEPTH OF RESERVOIR : 136.0 (m) (determined from diagram)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 136.00 m
MAXIMUM VOLUME OF RESERVOIR : 100. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.0 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Crystalline schist, nearly vertical folication. Gneiss and mylonitic rock also present
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,382,384

Porto Colombia

DAM NAME : Porto Colombia
RESERVOIR NAME : Porto Columbia
COUNTRY : Brazil
RIVER : Grande
LOCATION OF CENTER OF RESERVOIR : 20.12S,48.35W
LOCATION OF DAM : 20.12S,48.52W
DAM TYPE : Earth () fill with concrete gravity section
DATE DAM COMPLETED : 1972
DATE OF START OF FILLING : Apr-1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N20E
STRUCTURAL HEIGHT OF DAM : 53. m
LENGTH OF DAM : 2000. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 50.35 m
MAXIMUM VOLUME OF RESERVOIR : 1460. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 30.0 (km) km
NOTES ON REGIONAL GEOLOGY : Flood basalts; local sandstone deposits.
REGIONAL GEOLOGY : Volcanic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Dam and Reservoir Foundation: Flood basalts.
SITE GEOLOGY : Volcanic
DATE OF FIRST SUSPECTED RIS EVENT : 24-Feb-1974
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Earthquake occurred under Porto Colombia as it reached maximum level and as Volta Grande was being impounded immediately upstream.
GENERAL NOTES : Macroearthquakes not recorded by ISC or NOAA.
RIS CATEGORY : Accepted () (weak case)
TYPE OF RIS : macro
GEOLOGY REFERENCES : 67,107,108,119,393

Punt dal Gall

DAM NAME : Punt dal Gall
RESERVOIR NAME : Lago di Gallo (Livigno)
COUNTRY : Italy/Switzerland
RIVER : Spol (Spoel)
LOCATION OF CENTER OF RESERVOIR : 46.58N,10.18E
PROVINCE OR REGION : Grischun
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1969
NOTES ON HISTORY OF IMPOUNDMENT : 80 m fill in 1968, 107 m in 1969 summer
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Has SE arm; main reservoir SW
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 130. (m) above lowest foundation
MAXIMUM DEPTH OF RESERVOIR : 128.7 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 128.70 m
MAXIMUM VOLUME OF RESERVOIR : 164. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 9.0 km
NOTES ON REGIONAL GEOLOGY : Lower Engadine dolomites, in the nappe of Sarl, a large overthrust mass of upper Triassic age. Norien Formation dolomites and limestones often alternating
REGIONAL GEOLOGY : Carbonate
AGE OF REGIONAL GEOLOGY : Triassic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Limestone with interbedded and interfingered dolomite, N10W 20W average attitude. Several NW-trending fractures in dam foundation
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Triassic
PREDOMINANT FRACTURE ORIENTATION : NW
GEOLOGY REFERENCES : 107,177

Pyramid

DAM NAME : Pyramid
RESERVOIR NAME : Pyramid Lake
COUNTRY : USA
RIVER : Piru Creek
LOCATION OF CENTER OF RESERVOIR : 34.66N,118.79W
LOCATION OF DAM : 34.63N,118.76W
PROVINCE OR REGION : California
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 118. (m) above lowest foundation
MAXIMUM DEPTH OF RESERVOIR : 108.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 108.00 m
MAXIMUM VOLUME OF RESERVOIR : 221. m3x10E6
SURFACE AREA OF RESERVOIR : 5.50 km2
LONGEST DIMENSION OF RESERVOIR : 4.0 km
TECTONIC PROVINCE : Transverse Ranges
REGIONAL STRESS REGIME : Compressional (); N-S compression E-W shearing (RL)
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Fine-grained argillite, weak particles; two shale units beneath downstream shell. Beds of argillite (549 m thick unit) strike parallel to dam axis, dip upstream 40 to 50 degrees. Rocks are Pliocene.
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Pliocene
NOTES ON FAULTING : San Andreas fault within 13 km of dam; highly active. San Gabriel probably not active since mid-Pliocene (possible minor Quaternary activity)
PREDOMINANT FAULT TYPE : Right-slip
AZIMUTH OF PREDOMINANT FAULTING : San Gabriel: N40W to N65W (); San Andreas N45N to N85W
DIP OF PREDOMINANT FAULTING : Vertical
MAXIMUM LENGTH OF FAULTS : San Gabriel: 100 km; San Andreas (1857 trace): 360.00 (km) km
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Between San Gabriel fault and San Andreas fault
NAME OF CLOSEST KNOWN FAULT : San Gabriel
DISTANCE TO CLOSEST KNOWN FAULT : 1.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Pliocene
GEOLOGY REFERENCES : 108,121,235,274

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Rihand


DAM NAME : Rihand
COUNTRY : India
RIVER : Rihand
LOCATION OF CENTER OF RESERVOIR : 24.11N,82.80E
LOCATION OF DAM : 24.26N,83.00E
PROVINCE OR REGION : Uttar Pradesh
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 81 m above ground
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 93. m
LENGTH OF DAM : 934. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 83.70 m
MAXIMUM VOLUME OF RESERVOIR : 10630. m3x10E6
SURFACE AREA OF RESERVOIR : 466.00 km2
LONGEST DIMENSION OF RESERVOIR : 42.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Granite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 51,106,289
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Rocky Reach

DAM NAME : Rocky Reach
RESERVOIR NAME : Lake Entiat
COUNTRY : USA
RIVER : Columbia
LOCATION OF CENTER OF RESERVOIR : 47.78N,120.17W
LOCATION OF DAM : 47.53N,120.27W
PROVINCE OR REGION : Washington
DAM TYPE : concrete gravity
DATE DAM COMPLETED : 1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 43 m above ground.
ORIENTATION OF RESERVOIR : N30E
STRUCTURAL HEIGHT OF DAM : 59. m
LENGTH OF DAM : 884. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 53.10 m
MAXIMUM VOLUME OF RESERVOIR : 802. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 56.0 km
NOTES ON REGIONAL GEOLOGY : Boundary between crystalline rocks of the North Cascades and Tertiary basalt flows of the Columbia Plateau.
REGIONAL GEOLOGY : Volcanic
TECTONIC PROVINCE : Columbia Plateau
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Columbia River channel terraces of Quaternary age overlying bedrock. Bedrock on west side includes pre-Tertiary Methow Gneiss in southern reservoir area, Chelan Batholithic Complex in north area; overlain by Miocene Grande Ronde Basalt on east.
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Miocene
NOTES ON FAULTING : Southern end of Entiat fault is less than 5 km west of dam; normal fault, upthrown on east, NNW trend, 85 km long. Unnamed normal fault, pre Mio-Pliocene displacement, is 20 km east of reservoir and 17 km long. Orondo fault and related structures, all normal, north side upthrown, adjacent to east side of reservoir, length 1 km, displacement Plio-Pleistocene.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N25W () (Entiat fault); E-W (Orondo fault)
MAXIMUM LENGTH OF FAULTS : 85.00 (km) km
DOMINANT SIDE UP : E (); east (Entiant fault)
LOCATION OF RESERVOIR IN RELATION TO FAULTS : upthrown block () of Entiat fault, intersected by Orondo fault.
NAME OF CLOSEST KNOWN FAULT : Orondo
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km; in reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Plio-Pleistocene
SEISMICITY ASSOCIATED WITH FAULTS IN LOCAL AREA? : yes
DEGREE OF TOPOGRAPHIC RELIEF : moderate
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Seismicity spatially associated with water level, but no association with water levels. No change in levels of either microseismicity of macroseismicity after impoundment.
GENERAL NOTES : Data reliability is low.
RIS CATEGORY : not RIS
TYPE OF RIS : <none>
GEOLOGY REFERENCES : Woodward-Clyde Consultants, R. Withers; 106,203,418

## Roselend

DAM NAME : Roselend
COUNTRY : France
RIVER : Doron de Beaufort
LOCATION OF CENTER OF RESERVOIR : 45.68N, 6.63E
PROVINCE OR REGION : Savoie
DAM TYPE : Gravity () buttress
DATE DAM COMPLETED : 1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 124.5 m above ground; butterfly-shaped reservoir
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 150. m
LENGTH OF DAM : 806. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 132.00 m
MAXIMUM VOLUME OF RESERVOIR : 187. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.5 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Gneiss and hard crystalline schist, few fractures
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106, 289

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Ross


DAM NAME : Ross
RESERVOIR NAME : Ross Lake
COUNTRY : USA
RIVER : Skagit
LOCATION OF CENTER OF RESERVOIR : 48.88N,121.07W
PROVINCE OR REGION : Washington
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1949
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower () and flood control
NOTES ON DAM : Dam height 148 m above ground
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 165. (m) m from found.
LENGTH OF DAM : 396. m
MAXIMUM DEPTH OF RESERVOIR : 125.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 125.00 m
MAXIMUM VOLUME OF RESERVOIR : 1733. m3x10E6
SURFACE AREA OF RESERVOIR : 51.00 km2
LONGEST DIMENSION OF RESERVOIR : 32.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Gneiss and granite
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,289
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Round Butte

DAM NAME : Round Butte
RESERVOIR NAME : Lake Billy Chinook
COUNTRY : USA
RIVER : Deschutes
LOCATION OF CENTER OF RESERVOIR : 44.58N,121.28W
PROVINCE OR REGION : Oregon
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 128 m above ground; butterfly-shaped reservoir
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 134. (m) m above found.
LENGTH OF DAM : 402. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 120.60 m
MAXIMUM VOLUME OF RESERVOIR : 703. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 17.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Basalts and basaltic sediments, flat-lying interbedded; joints, perlite; Pliocene
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Pliocene
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : NW ()-trending
MAXIMUM LENGTH OF FAULTS : 80.00 (km) km (Bend fault)
NAME OF CLOSEST KNOWN FAULT : Fault along Whitewater R.
DISTANCE TO CLOSEST KNOWN FAULT : Whitewater fault begins at NW end reservoir, distance 1.0 (km) km; Bend/Jefferson fault 20 km away
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Late Cenozoic on Whitewater R., Late Tertiary to Quaternary (Bend fault)
GEOLOGY REFERENCES : 106,224,337

Rybinsk

DAM NAME : Rybinsk
RESERVOIR NAME : Rybinskoje Vdkhr.
COUNTRY : USSR
RIVER : Volga
LOCATION OF CENTER OF RESERVOIR : 58.50N,38.42E
LOCATION OF DAM : 58.05N,38.88E
PROVINCE OR REGION : Yaroslavl'
DAM TYPE : Earth () buttress and gravity spillway section
DATE DAM COMPLETED : 1941
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : 3 to 5 m annually; Hydropower () is principal use
NOTES ON DAM : Two dams on two rivers; taller one is 34 m high, other is 30 m high.
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 34. m
LENGTH OF DAM : 470. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 32.30 m
MAXIMUM VOLUME OF RESERVOIR : 25400. m3x10E6
SURFACE AREA OF RESERVOIR : 4550.00 km2
LONGEST DIMENSION OF RESERVOIR : 140.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : 4 to 4.8 m thick gravelly sand alluvium underlain by 1000 m thick Permian-Triassic shale
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Triassic
GEOLOGY REFERENCES : 76,106,152,306,330A

Saad-El-Aali (Aswan High)

DAM NAME : Saad-El-Aali (Aswan High)
RESERVOIR NAME : Lake Nasser
COUNTRY : Egypt
RIVER : Nile
LOCATION OF CENTER OF RESERVOIR : 22.65N,32.13E
LOCATION OF DAM : 24.00N,32.60E
PROVINCE OR REGION : Aswan
DAM TYPE : Rock ()fill
DATE DAM COMPLETED : 1970
NOTES ON HISTORY OF IMPOUNDMENT : Slow filling of reservoir up through 1971
DATE OF START OF FILLING : 1964
RATE OF INITIAL FILLING : 0.47 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 8.00 (years) years
MAXIMUM RATE OF FILLING : 4.00 (m/month) m/month in late 1966; 24 m in 6 months
MAXIMUM RATE OF DRAWDOWM : 1.40 (m/month) m/month in early 1966; 12 m in 5 months
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
ORIENTATION OF RESERVOIR : SE
STRUCTURAL HEIGHT OF DAM : 111. m
LENGTH OF DAM : 3830. m
MAXIMUM DEPTH OF RESERVOIR : 84.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 84.00 m
MAXIMUM VOLUME OF RESERVOIR : 164000. m3x10E6
SURFACE AREA OF RESERVOIR : 6220.00 km2
LONGEST DIMENSION OF RESERVOIR : 500.0 km
NOTES ON REGIONAL GEOLOGY : Nubian sandstones and underlying granitics. To the west, an extensive desert plain. To the east, desert plain truncated on the east by metamorphic and igneous rocks of the Eastern Desert
REGIONAL GEOLOGY : Coarse clastic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Granite, locally outcropping, overlain by nearly horizontal sandstone and shale of Nubian sandstone in reservoir area. Granite and migmatite underlie dam foundations, 130 m of alluvium in canyon, and strike-slip fault beneath alluvium in center of canyon
SITE GEOLOGY : Coarse clastic
DEGREE OF DEFORMATION : Flatlying
NOTES ON FAULTING : E-W faults in Wadi Kalabsha faulted complex healed with siliceous or iron oxide cement
PREDOMINANT FRACTURE ORIENTATION : E to W
PERMEABILITY OF ROCKS : Low (), maximum permeability 0.0003 cubic m/sec
TYPE OF PERMEABILITY : Intergranular
GROUNDWATER GRADIENT : High (); porosity 25%, maximum gradient 0.0023 in 1969
DEGREE OF TOPOGRAPHIC RELIEF : Low
GEOLOGY REFERENCES : 1,106,254,371

Sakuma

DAM NAME : Sakuma
RESERVOIR NAME : Sakuma-Ko
COUNTRY : Japan
RIVER : Tenryu
LOCATION OF CENTER OF RESERVOIR : 35.13N,137.78E
LOCATION OF DAM : 35.08N,137.78E
PROVINCE OR REGION : Aichi
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1956
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 135 m above ground
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 156. m
LENGTH OF DAM : 294. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 126.00 m
MAXIMUM VOLUME OF RESERVOIR : 327. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 6.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Mesozoic granite with diabase dikes
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Mesozoic
GEOLOGY REFERENCES : 106,444,468A

Salime

DAM NAME : Salime
RESERVOIR NAME : Embalse de Salime
COUNTRY : Spain
RIVER : Navia
LOCATION OF CENTER OF RESERVOIR : 43.17N,6.75W
PROVINCE OR REGION : Oviedo
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1956
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 116 m above ground
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 134. m
LENGTH OF DAM : 250. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 116.00 m
MAXIMUM VOLUME OF RESERVOIR : 266. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 17.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Alluvium on schist
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,468A

Sambuco

DAM NAME : Sambuco
RESERVOIR NAME : Lago Sambuco
COUNTRY : Switzerland
RIVER : Maggia
LOCATION OF CENTER OF RESERVOIR : 46.46N, 8.65E
PROVINCE OR REGION : Ticino
DAM TYPE : Hollow gravity
DATE DAM COMPLETED : 1956
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 130. (m) m above lowest foundation
LENGTH OF DAM : 363. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.00 m
MAXIMUM VOLUME OF RESERVOIR : 63. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 5.0 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Augen-gneiss and schistose gneiss with biotite
SITE GEOLOGY : Metamorphic
MAXIMUM LENGTH OF FAULTS : 27.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : 12.0 (km) km
GEOLOGY REFERENCES : 106, 468B

San Esteban

DAM NAME : San Esteban
RESERVOIR NAME : Embalse de San Esteban
COUNTRY : Spain
RIVER : Sil
LOCATION OF CENTER OF RESERVOIR : 42.44N, 7.52W
PROVINCE OR REGION : Orense
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1955
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 111 m above ground
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 115. m
LENGTH OF DAM : 295. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 97.00 m
MAXIMUM VOLUME OF RESERVOIR : 213. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 28.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : granite and gneiss
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106, 289, 468A

San Luis

DAM NAME . San Luis
RESERVOIR NAME : San Luis
COUNTRY : USA
RIVER . San Luis Creek
LOCATION OF CENTER OF RESERVOIR : 37.07N, 121.13W
LOCATION OF DAM : 37.07N, 121.08W
PROVINCE OR REGION : California
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1966
DATE OF START OF FILLING : 1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation () and hydropower
NOTES ON DAM : Dam height of 116 m above ground; approximately circular reservoir.
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 116. m
LENGTH OF DAM : 5669. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 104.40 m
MAXIMUM VOLUME OF RESERVOIR : 2603. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 9.0 km
NOTES ON REGIONAL GEOLOGY : Near the western margin of the Central Valley of California in the eastern section of the California Coast Range. The Central Valley is a NNW-trending basin filled with more than 3000 m of Mesozoic and Cenozoic sedimentary units. The basin has been downdropped relative to the Coast Range along high angle faults.
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : Mesozoic
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Dam and reservoir foundation: Reservoir underlain by Franciscan Assemblage west of the Ortigalita fault, Great Valley sequence sediments to the west.
SITE GEOLOGY : Coasrse clastic
AGE OF SITE GEOLOGY : Mesozoic
NOTES ON FAULTING : Ortigalita fault, which has had Quaternary displacement, passes through the reservoir. Length 50 km, has Quaternary displacement. East side down, normal.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N30W
MAXIMUM LENGTH OF FAULTS : 50.00 (km) km
DOMINANT SIDE UP : W (); west
PREDOMINANT FRACTURE ORIENTATION : NW
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Through reservoir
NAME OF CLOSEST KNOWN FAULT : Ortigalita
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary, possibly Holocene
ARE LOCAL FAULTS ACTIVE? : yes
SEISMICITY ASSOCIATED WITH FAULTS IN LOCAL AREA? : yes
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No change in level of seismicity and no greater spatial association with reservoir subsequent to impoundment than prior to impoundment.
GENERAL NOTES : Data reliability is low. No data presented suggesting that activity subsequent to impoundment was different than that prior to impoundment.
RIS CATEGORY : Not RIS
TYPE OF RIS : <none>
GEOLOGY REFERENCES : 106, 222, 235, 310, 397

Sanford

DAM NAME : Sanford
RESERVOIR NAME : Lake Meridith
COUNTRY : USA
RIVER : Canadian
LOCATION OF CENTER OF RESERVOIR : 35.63N,101.67W
LOCATION OF DAM : 35.72N,101.56W
PROVINCE OR REGION : Texas
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1965
DATE OF START OF FILLING : 1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
NOTES ON DAM : Dam height of 64 m above ground
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 70. m
LENGTH OF DAM : 1964. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 66.50 m
MAXIMUM VOLUME OF RESERVOIR : 1736. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 29.0 km
NOTES ON REGIONAL GEOLOGY : Within the Amarillo Uplift and bordered to the east by the Anadarko Basin. The Canadian River is incised through Tertiary sedimentary units in the Lake Meredith area and is underlain by the Permian Ochoan series. This series consists primarily of salt and anhydrite units overlian by sandstone and shale.
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : Tertiary
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No clear association spatially or temporally between seismicity and reservoir.
GENERAL NOTES : Data reliability is low. One event subsequent to impoundment. Region of pre-impoundment seismicity. No data on which to base temporal or spacial relationships of seismic activity to the reservoir.
RIS CATEGORY : Not RIS
GEOLOGY REFERENCES : 106,331,414

Sanmenxia (Sanmen Gorge)

DAM NAME : Sanmenxia (Sanmen Gorge)
COUNTRY : China (PRC)
RIVER : Huang He (Huang Ho)
LOCATION OF CENTER OF RESERVOIR : 34.65N, 110.33E
LOCATION OF DAM : 34 66N, 111.00E
PROVINCE OR REGION : Henan (Honan)
DAM TYPE : gravity
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Y-shaped reservoir; rapid silting of reservoir
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 96. m
LENGTH OF DAM : 702. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 86.40 m
MAXIMUM VOLUME OF RESERVOIR : 35400. m3x10E6
SURFACE AREA OF RESERVOIR : 2350.00 km2
LONGEST DIMENSION OF RESERVOIR : 135.0 km
REGIONAL STRESS REGIME : Extensional () with shear component
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 108, 152

Santa Giustina

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DAM NAME : Santa Giustina
RESERVOIR NAME : Lago di Santa Giustina
COUNTRY : Italy
RIVER : Noce
LOCATION OF CENTER OF RESERVOIR : 46.37N,11.06E
PROVINCE OR REGION : Bolzano
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1950
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 137.5 m above ground
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 152. m
LENGTH OF DAM : 124. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 122.50 m
MAXIMUM VOLUME OF RESERVOIR : 183. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 6.5 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Upper Triassic dolomitic limestone; fissured, horizontal stratification
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Triassic
DEGREE OF DEFORMATION : Flatlying
GEOLOGY REFERENCES : 106,176A
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Santa Maria


DAM NAME : Santa Maria
RESERVOIR NAME : Santa Maria
COUNTRY : Switzerland
RIVER : Rein de Medel
LOCATION OF CENTER OF RESERVOIR : 46.58N,8.79E
PROVINCE OR REGION : Grischun
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 117. (m) m above lowest foundation
LENGTH OF DAM : 560. m
MAXIMUM DEPTH OF RESERVOIR : 93.0 (m) (calculated from topographic map)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 93.00 m
MAXIMUM VOLUME OF RESERVOIR : 70. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 2.5 (km) (from topo. map)
NOTES ON REGIONAL GEOLOGY : Paleozoic St. Gotthard massif, with Mesozoic cover
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Paleozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Paleozoic granite, granitoid gneiss, and micaschist; Triassic schist; Jurassic marls
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Mesozoic
MAXIMUM LENGTH OF FAULTS : 80.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : 11.0 (km) km
GEOLOGY REFERENCES : 106,440A,440B
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Saratov

DAM NAME : Saratov
RESERVOIR NAME : Saratovskoye Vdkhr.
COUNTRY : USSR
RIVER : Volga
LOCATION OF CENTER OF RESERVOIR : 53.87N,48.37E
LOCATION OF DAM : 53.06N,47.75E
PROVINCE OR REGION : Saratov
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 40. (m) m
LENGTH OF DAM : 11340. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 38.00 m
MAXIMUM VOLUME OF RESERVOIR : 12900. m3x10E6
SURFACE AREA OF RESERVOIR : 1950.00 km2
LONGEST DIMENSION OF RESERVOIR : 215.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Sandy and clayey alluvium
GEOLOGY REFERENCES : 106,152,330A

Sarrans

DAM NAME : Sarrans
COUNTRY : France
RIVER : La Truyere
LOCATION OF CENTER OF RESERVOIR : 44.88N,2.90E
PROVINCE OR REGION : Aveyron
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1932
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 105 m above ground
ORIENTATION OF RESERVOIR : N75E
STRUCTURAL HEIGHT OF DAM : 113. m
LENGTH OF DAM : 220. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 95.00 m
MAXIMUM VOLUME OF RESERVOIR : 296. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 20.0 km
TECTONIC PROVINCE : Massif Central
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Granite with large parallelepiped structure of fractures.
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,176a

Sautet

DAM NAME : Sautet
COUNTRY : France
RIVER : Drac
LOCATION OF CENTER OF RESERVOIR : 44.81N, 5.94E
PROVINCE OR REGION : Isere
DAM TYPE : Concrete arch () gravity
DATE DAM COMPLETED : 1934
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Y-shaped reservoir
ORIENTATION OF RESERVOIR : SE.
STRUCTURAL HEIGHT OF DAM : 130. (m) above lowest foundation
LENGTH OF DAM : 80. m
MAXIMUM DEPTH OF RESERVOIR : 126.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 126.00 m
MAXIMUM VOLUME OF RESERVOIR : 130. m3x10E6
SURFACE AREA OF RESERVOIR : 3.50 km2
LONGEST DIMENSION OF RESERVOIR : 5.5 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Jurassic limestone alternating with schistose marl, which erode differentially; highly fractured. Reservoir includes preglacial stream channel filled by alluvial gravels and overlain by moraines (moraine development caused abandonment).
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Jurassic
NOTES ON HYDROLOGY : Permeability of rocks: high in abandoned channel in Quaternary sediments; unknown in bedrock.
GEOLOGY REFERENCES : 106, 176A, 468A

Schlegeis

DAM NAME : Schlegeis
RESERVOIR NAME : Schlegeis-Talsperre
COUNTRY : Austria
RIVER : Zemm
LOCATION OF CENTER OF RESERVOIR : 47.07N, 11.77E
LOCATION OF DAM : 47.13N, 11.82E
PROVINCE OR REGION : Tyrol
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1971
DATE OF START OF FILLING : Jul-1970
RATE OF INITIAL FILLING : 7.00 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 1.17 (years) years; 14 months
MAXIMUM RATE OF FILLING : 35.00 (m/month) m/month, July-August-1970
MAXIMUM RATE OF DRAWDOWM : 25.00 (m/month) m/month, March-April-1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 117 m above ground
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 130. (m) above foundation
LENGTH OF DAM : 722. m
MAXIMUM DEPTH OF RESERVOIR : 113.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 113.00 m
MAXIMUM VOLUME OF RESERVOIR : 128. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 8.0 km
NOTES ON REGIONAL GEOLOGY : Granite and granite gneiss in northern Alps
REGIONAL GEOLOGY : Batholithic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Site geology: Granite
SITE GEOLOGY : Batholithic
DATE OF FIRST SUSPECTED RIS EVENT : Sep-1971
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No influence on macroseismicity. Good correlation between microseismicity under or near the reservoir and changes in water level.
GENERAL NOTES : Data reliability is moderate. No pre-impoundment monitoring. Very small events recorded. Activity increase corresponds with low water levels.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 52, 53, 54, 55, 107, 418

Sefid Rud (Empress Farah)

DAM NAME : Sefid Rud (Empress Farah)
COUNTRY : Iran
RIVER : Sefid Rud
LOCATION OF CENTER OF RESERVOIR : 36.75N, 49.37E
PROVINCE OR REGION : Gilan
DAM TYPE : Concrete buttress gravity
DATE DAM COMPLETED : 1962
DATE OF START OF FILLING : Jan-1962
RATE OF INITIAL FILLING : 12.40 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 1.00 (years) year
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Dam height 85 m above ground.
STRUCTURAL HEIGHT OF DAM : 106. (m) above foundation
LENGTH OF DAM : 425. (m) m
MAXIMUM DEPTH OF RESERVOIR : 80.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 80.00 m
MAXIMUM VOLUME OF RESERVOIR : 1800. m3x10E6
SURFACE AREA OF RESERVOIR : 56.00 km2
LONGEST DIMENSION OF RESERVOIR : 35.0 (km) km
NOTES ON REGIONAL GEOLOGY : Moderately to highly folder Mesozoic deposits
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Alborz of Iran
REGIONAL STRESS REGIME : Compressional (); direction of maximum shortening is SW-NE
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Intermediate extrusive rocks at dam
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Early Tertiary
NOTES ON FAULTING : Reservoir is approximately equi-distant from two faults located 40-50 km NW and SE of reservoir
PREDOMINANT FAULT TYPE : High-angle reverse () and normal
AZIMUTH OF PREDOMINANT FAULTING : N80W
DIP OF PREDOMINANT FAULTING : 60NE to vertical
MAXIMUM LENGTH OF FAULTS : 45.00 (km) km
DOMINANT SIDE UP : S (); south
PREDOMINANT FRACTURE ORIENTATION : N50W to N89W (), locally to N70E
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block
NAME OF CLOSEST KNOWN FAULT : Rudbar
DISTANCE TO CLOSEST KNOWN FAULT : 40.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Late Tertiary
ARE LOCAL FAULTS ACTIVE? : Yes
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : 2-Aug-1968
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.7
DATE OF LARGEST SUSPECTED RIS EVENT : 2-Aug-1968
NOTES ON SEISMICITY AFTER IMPOUNDMENT : No change in level of macroseismicity prior to impoundment. Proximity of microseismicity to reservoir could not be evaluated from available date; no clear correlation between activity and water level changes. Macroseismicity spatially related to reservoir, occurred more than 6.5 years after filling began; no clear relationship to water level changes.
GENERAL NOTES : Several earthquakes in September and October of 1962 at 30 to 50 km from dam site may be related to filling if the location accuracy is poor.

RIS CATEGORY : Questionable
TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 46, 106, 296, 318, 448, 449

Serre-Poncon

DAM NAME : Serre-Poncon
COUNTRY : France
RIVER : Durance
LOCATION OF CENTER OF RESERVOIR : 44.55N, 6.35E
LOCATION OF DAM : 44.47N, 6.28E
PROVINCE OR REGION : Hautes-Alpes
DAM TYPE : Earth
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower () and irrigation
NOTES ON DAM : Dam height 124.5 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 130. m
LENGTH OF DAM : 600. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 116.55 m
MAXIMUM VOLUME OF RESERVOIR : 1270. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 16.5 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Limestone and calcschist overlain by alluvium and ancient landslide; depth of alluvium as great as 100m.
SITE GEOLOGY : Metamorphic
NOTES ON HYDROLOGY : Thermal waters circulate in alluviumfrom gypsiferous schist.
GEOLOGY REFERENCES : 106, 176A

Sharavathi

DAM NAME : Sharavathi
COUNTRY : India
LOCATION OF CENTER OF RESERVOIR : 14.10N,76.82E
LOCATION OF DAM : 14.10N,76.82E
DAM TYPE : Earth
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 40. (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 38.00 m
NOTES ON REGIONAL GEOLOGY : Regional Geologic Setting: Margin of the Peninsular Shield of India.
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
SITE GEOLOGY : Metamorphic
GENERAL NOTES : Insufficient data available to evaluate. No local macroearthquakes reported by ISC.
RIS CATEGORY : Questionable
GEOLOGY REFERENCES : 96,106,192,195,203

DAM NAME : Shasta

RESERVOIR NAME : Lake Shasta

COUNTRY : USA

RIVER : Sacramento

LOCATION OF CENTER OF RESERVOIR : 40.77N,122.30W

LOCATION OF DAM : 40.72N,122.42W

PROVINCE OR REGION : California

DAM TYPE : Concrete arch () gravity

DATE DAM COMPLETED : 1944

DATE OF START OF FILLING : 1944

EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () is first listing

NOTES ON DAM : Dam height of 148 m above ground; multi-arm reservoir.

ORIENTATION OF RESERVOIR : N70E

STRUCTURAL HEIGHT OF DAM : 183. m

LENGTH OF DAM : 1057. m

RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 153.00 m

MAXIMUM VOLUME OF RESERVOIR : 5615. m3x10E6

SURFACE AREA OF RESERVOIR : 119.00 km2

LONGEST DIMENSION OF RESERVOIR : 40.0 km

NOTES ON REGIONAL GEOLOGY : Klamath Mountains province of northern California. Province is characterized by Paleozoic and Mesozoic eugeosynclinal sequences of clastic and volcanic units that have been metamorphosed along arcuate NE- to NW-trending belts and intruded by Mesozoic granitic plutons. The structural style of the province is characterized by Mesozoic E-W compression with low-angle thrust faulting.

REGIONAL GEOLOGY : Metamorphic

AGE OF REGIONAL GEOLOGY : Mesozoic

TECTONIC PROVINCE : Klamath Mountains

REGIONAL STRESS REGIME : Shear

EVIDENCE FOR REGIONAL STRESS REGIME : tectonics

CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium

NOTES ON SITE GEOLOGY : Dam and reservoir foundation: Dam is underlain by Paleozoic meta-andesites. Reservoir is underlain by Paleozoic and Mesozoic pyroclastic units, shale, sandstone, conglomerate, breccia, mudstone and tuffs with local units of limestone and chert. Units have all been subjected to metamorphism during Mesozoic orogenies.

SITE GEOLOGY : Metamorphic

AGE OF SITE GEOLOGY : Mesozoic

NOTES ON FAULTING : Reservoir is underlain in part by the Spring Creek thrust fault of pre-Quaternary age. NNW-trending and NE-trending pre-Quaternary normal and reverse faults underlie various parts of the reservoir and nearby vicinity. Faults are reported to have mid-Mesozoic displacement. Longest fault Spring Creek thrust, 50 km long.

PREDOMINANT FAULT TYPE : reverse

MAXIMUM LENGTH OF FAULTS : 50.00 (km) km

LOCATION OF RESERVOIR IN RELATION TO FAULTS : Through reservoir

NAME OF CLOSEST KNOWN FAULT : Spring Creek fault

DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km

DATE OF FIRST SUSPECTED RIS EVENT : 1944

NOTES ON SEISMICITY AFTER IMPOUNDMENT : Swarm of small events occurred subsequent to reservoir impoundment. No subsequent activity was reported. Largest events occurred a few kilometers southeast of the reservoir. Focal depths not obtained.

GENERAL NOTES : Data reliability is low. Weak correlation between microseismicity and initial impoundment. Macroseismicity poorly related to filling of reservoir.

RIS CATEGORY : Accepted

TYPE OF RIS : micro

GEOLOGY REFERENCES : 84,92,106,221,235,289,309,386,418 .

Shihmen

DAM NAME : Shihmen
RESERVOIR NAME : Shihmen
COUNTRY : Taiwan
RIVER : Takekan Creek
LOCATION OF CENTER OF RESERVOIR : 24.84N,121.25E
DAM TYPE : Earth () and rock fill
DATE DAM COMPLETED : 1964
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 133. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 119.70 m
MAXIMUM VOLUME OF RESERVOIR : 316. m3x10E6
SURFACE AREA OF RESERVOIR : 8.00 km2
LONGEST DIMENSION OF RESERVOIR : 16.5 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
SITE GEOLOGY : Coarse clastic
AGE OF SITE GEOLOGY : Miocene, Pliocene
PREDOMINANT FAULT TYPE : Reverse
NAME OF CLOSEST KNOWN FAULT : Hsintien fault
GEOLOGY REFERENCES : 106,266

Shimokotori

DAM NAME : Shimokotori
COUNTRY : Japan
RIVER : Kotoro
PROVINCE OR REGION : Gifu
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 199. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 179.10 m
MAXIMUM VOLUME OF RESERVOIR : 123. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Gneiss and granite
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,289

Shimokubo

DAM NAME : Shimokubo
COUNTRY : Japan
RIVER : Kanna
LOCATION OF CENTER OF RESERVOIR : 36.18N,139.01W
PROVINCE OR REGION : Gumma
DAM TYPE : Concrete gravity
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () listed first
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 129. (m) m above lowest foundation
LENGTH OF DAM : 626. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 111.00 m
MAXIMUM VOLUME OF RESERVOIR : 130. m3x10E6
SURFACE AREA OF RESERVOIR : 3.27 km2
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Limestone, green schist, and quartz schist
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,233,470,471

## Shintoyone

DAM NAME : Shintoyone
COUNTRY : Japan
RIVER : Onyu
LOCATION OF CENTER OF RESERVOIR : 35.13N,137.75E
PROVINCE OR REGION : Aichi
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower () and flood control
ORIENTATION OF RESERVOIR : SE
STRUCTURAL HEIGHT OF DAM : 117. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 99.00 m
MAXIMUM VOLUME OF RESERVOIR : 54. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 4.5 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Mesozoic granite with diabase dikes
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Mesozoic
GEOLOGY REFERENCES : 107,108,444

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Sholayar


DAM NAME : Sholayar
RESERVOIR NAME : Sholayar
COUNTRY : India
RIVER : Sholayar
LOCATION OF CENTER OF RESERVOIR : 10.31N,76.77E
LOCATION OF DAM : 10.32N,76.73E
DAM TYPE : Concrete gravity () with earth section
DATE DAM COMPLETED : 1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower (), irrigation
NOTES ON DAM : Dam height of 58 m above ground
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 66. m
LENGTH OF DAM : 426. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 59.40 m
MAXIMUM VOLUME OF RESERVOIR : 154. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 8.0 (km) km
NOTES ON REGIONAL GEOLOGY : Margin of the Peninsular Shield of India.
REGIONAL GEOLOGY : Metamorphic
AGE OF REGIONAL GEOLOGY : Archaean
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Archaean
PREDOMINANT FAULT TYPE : Normal
NAME OF CLOSEST KNOWN FAULT : Palaghat Gap
DISTANCE TO CLOSEST KNOWN FAULT : 4.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Miocene
GENERAL NOTES : Insufficient data available to evaluate.  No macroearthquakes reported by ISC near dam.
RIS CATEGORY : Questionable
GEOLOGY REFERENCES : 93,192,195,203,379
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# So Yang Gang

DAM NAME : So Yang Gang
COUNTRY : Korea
RIVER : Han
PROVINCE OR REGION : Gangweondo
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 123. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 110.70 m
MAXIMUM VOLUME OF RESERVOIR : 2900. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 107,108

Soria

DAM NAME : Soria
COUNTRY : Canary Islands, Spain
RIVER : Barranco Soria
LOCATION OF CENTER OF RESERVOIR : 27.91N, 15.65W
PROVINCE OR REGION : Gran Canaria
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1972
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 130. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.00 m
MAXIMUM VOLUME OF RESERVOIR : 40. m3x10E6
SURFACE AREA OF RESERVOIR : 0.68 km2
LONGEST DIMENSION OF RESERVOIR : 3.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Trachiriolitic volcanic complex, deep milontized or clay-filled fractures in three directions
SITE GEOLOGY : Volcanic
GEOLOGY REFERENCES : 104A, 107

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Sounda          (Kouilou)

DAM NAME : Sounda          (Kouilou)
COUNTRY : Congo
RIVER : Kouila (Kouilou)
DATE DAM COMPLETED : 1977
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 137. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 123.00 (m) m
MAXIMUM VOLUME OF RESERVOIR : 35000. m3x10E6
SURFACE AREA OF RESERVOIR : 1600.00 km2
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 418
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Speccheri


DAM NAME : Speccheri
COUNTRY : Italy
RIVER : Leno di Vallarsa
LOCATION OF CENTER OF RESERVOIR : 46.42N,11.38E
PROVINCE OR REGION : Trento
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 108 m above ground
STRUCTURAL HEIGHT OF DAM : 157. m
LENGTH OF DAM : 192. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 127.00 m
MAXIMUM VOLUME OF RESERVOIR : 10. m3x10E6
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Limestone
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 106,289
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Summersville

DAM NAME : Summersville
RESERVOIR NAME : Summersville Lake
COUNTRY : USA
RIVER : Gauley
LOCATION OF CENTER OF RESERVOIR : 38.21N, 80.83W
PROVINCE OR REGION : West Virginia
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Flood control () listed first
NOTES ON DAM : Dam height 111 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 121. (m) m above foundation
LENGTH OF DAM : 695. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 108.90 m
MAXIMUM VOLUME OF RESERVOIR : 510. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 19.0 km
TECTONIC PROVINCE : Appalachians
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 106

Susqueda

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DAM NAME : Susqueda
RESERVOIR NAME : Embalse de Susqueda
COUNTRY : Spain
RIVER : Tera
LOCATION OF CENTER OF RESERVOIR : 41.95N,2.49E
PROVINCE OR REGION : Gerona
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () listed first
NOTES ON DAM : Dam height 120 m above ground
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 135. (m) m above foundation
LENGTH OF DAM : 510. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 117.00 m
MAXIMUM VOLUME OF RESERVOIR : 235. m3x10E6
SURFACE AREA OF RESERVOIR : 18.00 km2
LONGEST DIMENSION OF RESERVOIR : 18.0 km
NOTES ON REGIONAL GEOLOGY : Gneiss and meta-diorite with Hercinian granitic porphyry veins
REGIONAL GEOLOGY : Metamorphic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
SITE GEOLOGY : Metamotphic
GEOLOGY REFERENCES : 104A,106
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Swift Creek

DAM NAME : Swift Creek
RESERVOIR NAME : Swift Creek Reservoir
COUNTRY : USA
RIVER : Lewis
LOCATION OF CENTER OF RESERVOIR : 46.07N,122.08W
LOCATION OF DAM : 46.00N,122.23W
PROVINCE OR REGION : Washington
DAM TYPE : Earth
DATE DAM COMPLETED : 1958
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 126 m above ground
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 156. (m) m above foundation
LENGTH OF DAM : 640. m
MAXIMUM DEPTH OF RESERVOIR : 116.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 116.00 m
MAXIMUM VOLUME OF RESERVOIR : 932. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 15.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Alluvium including bouldery gravel, sand, and gravel, 61 m thick
GEOLOGY REFERENCES : 41,106,289

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Tabka           (Tabga, Thawra)


DAM NAME : Tabka           (Tabga, Thawra)
RESERVOIR NAME : Lake Assad
COUNTRY : Syria
RIVER : Euphrates
LOCATION OF CENTER OF RESERVOIR : 35.92N,38.25E
LOCATION OF DAM : 35.87N,38.58E
PROVINCE OR REGION : Aleppo
DAM TYPE : Earth
DATE DAM COMPLETED : 1976
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation (), hydropower
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 60. m
LENGTH OF DAM : 4500. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 57.00 m
MAXIMUM VOLUME OF RESERVOIR : 14000. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 55.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 108,306
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Tachien

DAM NAME : Tachien
RESERVOIR NAME : Tachien
COUNTRY : Taiwan
RIVER : Tachia
LOCATION OF CENTER OF RESERVOIR : 24.27N,121.23E
LOCATION OF DAM : 24.25N,121.16E
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1974
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply
ORIENTATION OF RESERVOIR : N65E
STRUCTURAL HEIGHT OF DAM : 181. m
LENGTH OF DAM : 232. m
MAXIMUM DEPTH OF RESERVOIR : 172.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 172.00 m
MAXIMUM VOLUME OF RESERVOIR : 232. m3x10E6
SURFACE AREA OF RESERVOIR : 4.50 km2
LONGEST DIMENSION OF RESERVOIR : 14.0 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Yonryo quartzite, massive, local shale and slate interbeds, Eocene, attitude N50W 60SE. Suichioriu slate 2000 m +, Oligocene
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Eocene
ORIENTATION OF STRUCTURAL GRAIN : N50W
DEGREE OF DEFORMATION : Steeply dipping
NOTES ON FAULTING : Fault mapped just upstream of dam, not through abutment. Controls course of river. Type, age, etc. unknown.
GEOLOGY REFERENCES : 108,236,469

Tagokura

DAM NAME : Tagokura
COUNTRY : Japan
RIVER : Tadami
PROVINCE OR REGION : Fukushima
DAM TYPE : Gravity
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 123 m above ground
STRUCTURAL HEIGHT OF DAM : 145. (m) m above foundation
LENGTH OF DAM : 462. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 127.00 m
MAXIMUM VOLUME OF RESERVOIR : 494. m3x10E6
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Post Neocene liparite, tuff, other volcanics
SITE GEOLOGY : Volcanic
GEOLOGY REFERENCES : 106,347

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Takane No. 1


DAM NAME : Takane No. 1
COUNTRY : Japan
RIVER : Hida
LOCATION OF CENTER OF RESERVOIR : 36.06N,137.42E
PROVINCE OR REGION : Gifu
DAM TYPE : Concrete dome arch
DATE DAM COMPLETED : 1969
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 133. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 115.00 m
MAXIMUM VOLUME OF RESERVOIR : 46. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Chert and porphyrite
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 107,233
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## Takase

DAM NAME : Takase
COUNTRY : Japan
RIVER : Takase
LOCATION OF CENTER OF RESERVOIR : 36.45N, 137.70E
DAM TYPE : Earth
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 176. m
MAXIMUM DEPTH OF RESERVOIR : 105.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 105.00 m
MAXIMUM VOLUME OF RESERVOIR : 76. m3x10E6
SURFACE AREA OF RESERVOIR : 1.78 km2
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Jurassic granite with diorite and porphyrite; alluvium 30-40 m thick at dam site
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Jurassic
GEOLOGY REFERENCES : 107,315

DAM NAME : Talbingo
RESERVOIR NAME : Talbingo
COUNTRY : Australia
RIVER : Tumut
LOCATION OF CENTER OF RESERVOIR : 35.72S,148.33E
LOCATION OF DAM : 35.63S,148.30E
PROVINCE OR REGION : New South Wales
DAM TYPE : Earth () and rock fill
DATE DAM COMPLETED : 1970
DATE OF START OF FILLING : May-1971
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 153 m above ground.
ORIENTATION OF RESERVOIR : S10E
STRUCTURAL HEIGHT OF DAM : 162. m
LENGTH OF DAM : 700. m
MAXIMUM DEPTH OF RESERVOIR : 142.0 (m) m (from drawing)
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 142.00 m
MAXIMUM VOLUME OF RESERVOIR : 935. m3x10E6
SURFACE AREA OF RESERVOIR : 19.40 km2
LONGEST DIMENSION OF RESERVOIR : 18.0 km
NOTES ON REGIONAL GEOLOGY : Snowy Mountains are primarily Paleozoic granitic units intruded into and overlain by steeply dipping Paleozoic metasedimentary strata, all of which are intruded by porphyry dikes. These units are overlain by Paleozoic rhyolite and Tertiary basalt. Faults and shear zones resulting from regional northwest-southeast-oriented compression include northeast-trending thrust faults and northwest-trending strike-slip faults.
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and reservoir foundation: Dam underlain by flat-lying Paleozoic rhyolite. Reservoir is underlain by the rhyolite, Paleozoic granite and Paleozoic metasedimentary strata.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Paleozoic
NOTES ON FAULTING : Post-Devonian displacement on a N20E-trending, near-vertical fault 30 km east. Northeast-trending Tawonga fault, 48 km southwest, has Pleistocene or younger displacements toward the northwest. A northwest-trending sinstral wrench fault, the Berridale fault, 15 km southeast, may be active, based on a transcurrent fault plane solution for seismicity on the Crackenback fault, 40 miles south.
PREDOMINANT FAULT TYPE : Left-slip
AZIMUTH OF PREDOMINANT FAULTING : NW
NAME OF CLOSEST KNOWN FAULT : Berridale fault
DISTANCE TO CLOSEST KNOWN FAULT : 15.0 (km) km
NOTES ON HYDROLOGY : Hydrology: Probably shallow water table reflecting topography, with seasonal fluctuations. Water in rock fractures and in crushed permeable zones along faults in region.
DEGREE OF TOPOGRAPHIC RELIEF : high
DATE OF FIRST SUSPECTED RIS EVENT : Jun-1971
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 3.5 (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 6-Jan-1973
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Seismic activity increased for 2 months during rapid initial filling of the reservoir beginning about 2 months after impoundment commenced. After initial increase in activity, seismic frequency declined as reservoir continued to fill at a less rapid rate. Activity reported to be located along faults.
GENERAL NOTES : Data reliability moderate to good. Pre-impoundment monitoring was conducted. Activity increased during initial impoundment. Most activity located in or near the reservoir.
RIS CATEGORY : Accepted

TYPE OF RIS : macro and micro
GEOLOGY REFERENCES : 40, 99, 100, 107, 114, 270, 321, 418, 456, 460, 481

Tarbela

DAM NAME : Tarbela
RESERVOIR NAME : Tarbela
COUNTRY : Pakistan
RIVER : Indus
LOCATION OF CENTER OF RESERVOIR : 34.13N, 72.79E
LOCATION OF DAM : 34.00N, 72.62E
PROVINCE OR REGION : Northwest frontier
DAM TYPE : Earth () fill with rock
DATE DAM COMPLETED : 1976
NOTES ON HISTORY OF IMPOUNDMENT : Filling started in 1974, 1975, 1976, 1977. First three fillings failed, and reservoir was emptied. Maximum height finally reached in 1977 after four-month period.
DATE OF START OF FILLING : 1974 () (1977)
RATE OF INITIAL FILLING : 34.00 (m/month) m/month
YEARS FROM BEGINNING TO MAXIMUM FILL : 0.29 (years) year during final filling
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Dam height of 143 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 143. m
LENGTH OF DAM : 2743. m
MAXIMUM DEPTH OF RESERVOIR : 137.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 137.00 m
MAXIMUM VOLUME OF RESERVOIR : 13690. m3x10E6
SURFACE AREA OF RESERVOIR : 243.00 km2
LONGEST DIMENSION OF RESERVOIR : 81.0 km
NOTES ON REGIONAL GEOLOGY : Approximately 50 km west of syntaxal axis of Himalayas. Regionally, igneous and metamorphic rocks as well as Devonian and Silurian sediments.
REGIONAL GEOLOGY : Coarse clastic
AGE OF REGIONAL GEOLOGY : Paleozoic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Alluvium 60 to 120 m, up to 180 m at dam site. Irregular bedrock contact.
NOTES ON HYDROLOGY : Permeability through alluvium of 0.01 cm per sec to 0.04 cm per sec; see page through alluvium at dam abutments.
GEOLOGY REFERENCES : 108, 228B, 250, 283, 284, 306

Tignes

DAM NAME : Tignes
RESERVOIR NAME : Lac du Chevril
COUNTRY : France
RIVER : Isere
LOCATION OF CENTER OF RESERVOIR : 45.47N,6.93E
LOCATION OF DAM : 45.49N,6.92E
PROVINCE OR REGION : Savoie
DAM TYPE : Concrete arch (), constant radius
DATE DAM COMPLETED : 1952
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam is 160 m above ground level
ORIENTATION OF RESERVOIR : S60E
STRUCTURAL HEIGHT OF DAM : 181. m
LENGTH OF DAM : 375. m
MAXIMUM DEPTH OF RESERVOIR : 155.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 155.00 m
MAXIMUM VOLUME OF RESERVOIR : 230. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 3.6 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Massive Triassic quartzite
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Triassic
GEOLOGY REFERENCES : 106,367,455

Tikves

DAM NAME : Tikves
COUNTRY : Yugoslavia
RIVER : Crna Reka
PROVINCE OR REGION : Makedonika
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation () and hydropower
NOTES ON DAM : 105 m above ground
STRUCTURAL HEIGHT OF DAM : 113. m
LENGTH OF DAM : 338. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 101.70 m
MAXIMUM VOLUME OF RESERVOIR : 475. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 106

## Toktogol

DAM NAME : Toktogol
COUNTRY : USSR
RIVER : Naryn
LOCATION OF DAM : 41.74N,72.79E
PROVINCE OR REGION : Kirghiz
DAM TYPE : Gravity
DATE DAM COMPLETED : 1977
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 215. m
LENGTH OF DAM : 450. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 185.00 m
MAXIMUM VOLUME OF RESERVOIR : 19500. m3x10E6
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 306,468

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Toxaway


DAM NAME : Toxaway
RESERVOIR NAME : Lake Toxaway
COUNTRY : USA
RIVER : Jocassee
LOCATION OF CENTER OF RESERVOIR : 35.13N,82.06W
PROVINCE OR REGION : South Carolina
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1972
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 122. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 109.80 m
MAXIMUM VOLUME OF RESERVOIR : 52. m3x10E6
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 107
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Trangslet


DAM NAME : Trangslet
COUNTRY : Sweden
RIVER : Osterdalalven
LOCATION OF CENTER OF RESERVOIR : 61.60N,13.20E
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Maximum fluctuation of 35 m; Hydropower
NOTES ON DAM : Dam height 125 m above ground
STRUCTURAL HEIGHT OF DAM : 125. m
LENGTH OF DAM : 850. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.50 m
MAXIMUM VOLUME OF RESERVOIR : 880. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Porphyritic syenite with diabase inclusions
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,289,360
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Tres Marias

DAM NAME : Tres Marias
COUNTRY : Brazil
RIVER : Barreiro Grande
LOCATION OF CENTER OF RESERVOIR : 18.20S,45.25W
PROVINCE OR REGION : Minas Gerais
DAM TYPE : Earth () with gravity spillway section
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose, Irrigation () is principle use.
STRUCTURAL HEIGHT OF DAM : 75. m
LENGTH OF DAM : 2700. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 71.25 m
MAXIMUM VOLUME OF RESERVOIR : 19300. m3x10E6
SURFACE AREA OF RESERVOIR : 1130.00 km2
LONGEST DIMENSION OF RESERVOIR : 95.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Silurian Bambui Series, metamorphic greenish- gray siltstones or sandstones and occasionally quartzites, overlain by Tertiary sediments.
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Silurian
GEOLOGY REFERENCES : 106,152

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Trinity


DAM NAME : Trinity
RESERVOIR NAME : Clair Engle Lake
COUNTRY : USA
RIVER : Trinity
LOCATION OF CENTER OF RESERVOIR : 40.87N,122.72W
LOCATION OF DAM : 40.78N,122.77W
PROVINCE OR REGION : California
DAM TYPE : Earth
DATE DAM COMPLETED : 1962
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation () and hydropower
NOTES ON DAM : Dam height 142 m above ground; v-shaped reservoir with dominant NNE arm.
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 164. (m) m above foundation
LENGTH OF DAM : 792. m
MAXIMUM DEPTH OF RESERVOIR : 134.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 134.00 m
MAXIMUM VOLUME OF RESERVOIR : 3084. m3x10E6
SURFACE AREA OF RESERVOIR : 66.00 km2
LONGEST DIMENSION OF RESERVOIR : 18.0 km
TECTONIC PROVINCE : Klamath Mts.
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Meta-andesite, low-grade metamorphics, Paleozoic or Mes., deep weathering along faults and joints
SITE GEOLOGY : Metamorphic
AGE OF SITE GEOLOGY : Mesozoic
NOTES ON FAULTING : Faults in vicinity of reservoir include both normal and thrust faults.  Thrust faults dominate in the regional
tectonic framework.
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : N30W to N30E
MAXIMUM LENGTH OF FAULTS : 15.00 (km) km
DOMINANT SIDE UP : E () (east) side of thrust faults
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block (); thrust west of main arm, intersects southern arm, normal faults at
north end.
NAME OF CLOSEST KNOWN FAULT : unnamed
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km, through reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Pre-Quaternary
GEOLOGY REFERENCES : 106,121,235,468B
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Tsengwen

DAM NAME : Tsengwen
RESERVOIR NAME : Tsengwen
COUNTRY : Taiwan
RIVER : Tsengwen
LOCATION OF CENTER OF RESERVOIR : 23.31N, 120.65E
DAM TYPE : Earth () and rock fill
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
NOTES ON DAM : Normal water depth of 116 m, maximum depth 123.5 m
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 130. (m) m above foundation
MAXIMUM DEPTH OF RESERVOIR : 123.5 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 123.50 m
MAXIMUM VOLUME OF RESERVOIR : 708. m3x10E6
SURFACE AREA OF RESERVOIR : 17.00 (km2) at normal level
LONGEST DIMENSION OF RESERVOIR : 16.0 (km) at normal level
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Reservoir: Miocene and Pliocene sandstone, mudstone, and shale. Several faults with gouge. Dam: Miocene sandstone, siltstone, and shale; N32E34E
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Miocene
ORIENTATION OF STRUCTURAL GRAIN : N32E
NOTES ON FAULTING : Reservoir crosses Chutouchi fault and is subparallel to chuko fault.  Chuko is reportedly active and is discussed in following values.
PREDOMINANT FAULT TYPE : Reverse
AZIMUTH OF PREDOMINANT FAULTING : N20E
MAXIMUM LENGTH OF FAULTS : 75.00 (km) km to 150 km
DOMINANT SIDE UP : E (); east
LOCATION OF RESERVOIR IN RELATION TO FAULTS : upthrown block () of Chuko fault
NAME OF CLOSEST KNOWN FAULT : 3 km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Holocene
ARE LOCAL FAULTS ACTIVE? : Yes
GEOLOGY REFERENCES : 108, 266, 276

Tsimlyansk

DAM NAME : Tsimlyansk
RESERVOIR NAME : Tsimlyanskoye Vdkhr.
COUNTRY : USSR
RIVER : Don
LOCATION OF CENTER OF RESERVOIR : 48.00N, 43.00E
LOCATION OF DAM : 47.61N, 42.12E
PROVINCE OR REGION : Rostov
DAM TYPE : Earth () buttress with gravity spillway section
DATE DAM COMPLETED : 1952
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose, Hydropower () is principal use
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 39, m
LENGTH OF DAM : 13232. m
MAXIMUM DEPTH OF RESERVOIR : 30.0 (m) m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 30.00 m
MAXIMUM VOLUME OF RESERVOIR : 21850. m3x10E6
SURFACE AREA OF RESERVOIR : 2700.00 km2
LONGEST DIMENSION OF RESERVOIR : 230.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Alluvial sands and loess overlying Tertiary shale, claystone, and sandstone.
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Tertiary
GEOLOGY REFERENCES : 106, 152, 330A

Tsuruta

DAM NAME : Tsuruta
COUNTRY : Japan
RIVER : Sendai
PROVINCE OR REGION : Kagoshima
DAM TYPE : Gravity
DATE DAM COMPLETED : 1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control () and hydropower
NOTES ON DAM : Dam height 105 m above ground
STRUCTURAL HEIGHT OF DAM : 118. m
LENGTH OF DAM : 448. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 100.00 m
MAXIMUM VOLUME OF RESERVOIR : 123. m3x10E6
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Granite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,289

Ukai

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DAM NAME : Ukai
COUNTRY : India
RIVER : Tapi
LOCATION OF DAM : 21.25N,73.72E ().E
DAM TYPE : Earth () fill, rock fill, center concrete gravity.
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Irrigation
STRUCTURAL HEIGHT OF DAM : 69. m
LENGTH OF DAM : 4926. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 65.55 m
MAXIMUM VOLUME OF RESERVOIR : 8511. m3x10E6
SURFACE AREA OF RESERVOIR : 520.00 km2
NOTES ON REGIONAL GEOLOGY : Margin of the Peninsular Shield of India.
REGIONAL GEOLOGY : Volcanic
AGE OF REGIONAL GEOLOGY : Cretaceous to Oligocene
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
SITE GEOLOGY : Volcanic
AGE OF SITE GEOLOGY : Cretaceous to Oligocene
NOTES ON FAULTING : Fault through abutment,speculated Tertiary age
PREDOMINANT FAULT TYPE : Normal
DISTANCE TO CLOSEST KNOWN FAULT : 0.0 (km) km
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Tertiary; post Oligocene
GENERAL NOTES : Insufficient data available to evaluate.  No macroearthquakes located near dam.
RIS CATEGORY : Questionable
GEOLOGY REFERENCES : 108,192,195,196,203,230,284B,285,323
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Union Valley

DAM NAME : Union Valley
RESERVOIR NAME : Union Valley
COUNTRY : USA
RIVER : Silver Creek
LOCATION OF CENTER OF RESERVOIR : 38.83N,120.43W
PROVINCE OR REGION : California
DAM TYPE : Earth
DATE DAM COMPLETED : 1963
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower () and recreation
NOTES ON DAM : Dam height 132 m above ground
ORIENTATION OF RESERVOIR : NE
STRUCTURAL HEIGHT OF DAM : 132. m
LENGTH OF DAM : 533. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 118.80 m
MAXIMUM VOLUME OF RESERVOIR : 334. m3x10E6
SURFACE AREA OF RESERVOIR : 11.60 km2
LONGEST DIMENSION OF RESERVOIR : 4.0 km
NOTES ON REGIONAL GEOLOGY : Near boundary between Paleozoic Calaveras and Shoe Fly Formations and Mesozoic granitic intrusives of the Sierran batholith
REGIONAL GEOLOGY : Batholithic
AGE OF REGIONAL GEOLOGY : Cretaceous
TECTONIC PROVINCE : Sierra Nevada
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and reservoir in Sierran granitics
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Cretaceous
NOTES ON FAULTING : Union Valley Reservoir located between Quaternary faults of the Lake Tahoe basin and late Cenozoic strands of the Foothills fault system. Data are provided on Tahoe Basin.
PREDOMINANT FAULT TYPE : Normal
AZIMUTH OF PREDOMINANT FAULTING : N40W to N25W () (Sierran/Tahoe Basin faults)
MAXIMUM LENGTH OF FAULTS : 21.00 (km) km (Tahoe Basin)
DOMINANT SIDE UP : W (); west
LOCATION OF RESERVOIR IN RELATION TO FAULTS : Upthrown block (), Sierran/Tahoe
NAME OF CLOSEST KNOWN FAULT : Tahoe Basin
DISTANCE TO CLOSEST KNOWN FAULT : 25.0 (km) km; short fault of unknown age located 14 km to east of reservoir
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Quaternary
ARE LOCAL FAULTS ACTIVE? : No (); faults not in local area.
GEOLOGY REFERENCES : Woodward-Clyde Consultants,106,121,235

Vajont

DAM NAME : Vajont
RESERVOIR NAME : Vajont
COUNTRY : Italy
RIVER : Vajont
LOCATION OF CENTER OF RESERVOIR : 46.27N,12.38E
LOCATION OF DAM : 46.27N,12.34E
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1960
DATE OF START OF FILLING : Feb-1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height of 259 m above ground.
ORIENTATION OF RESERVOIR : N70E
STRUCTURAL HEIGHT OF DAM : 262. m
LENGTH OF DAM : 425. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 232.00 m
MAXIMUM VOLUME OF RESERVOIR : 150. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 3.4 (km) km
NOTES ON REGIONAL GEOLOGY : In the Dolomite Mountains of the Dinaride section of the southern Alps. Mesozoic carbonate and local flysch deposits with southward thrust faulting along faults oriented primarily east-west.
REGIONAL GEOLOGY : Carbonate
AGE OF REGIONAL GEOLOGY : Mesozoic
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Dam and reservoir foundation: Middle Jurassic limestone, marl and clay. Reservoir also contains marl of Cretaceous and Eocene age of unknown composition.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Jurassic
NOTES ON FAULTING : Minor faults and fractures present. No additional data obtained.
DATE OF FIRST SUSPECTED RIS EVENT : 20-May-1960
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Clear correlation of microseismicity with initial impoundment and water level fluctuations. Some disagreement in the literature as to whether most events are tectonic or related to mobilization of landslide mass.
GENERAL NOTES : ISC reports magnitude 5.6 event close (12 km) to center of reservoir in 1936, some 24 years prefilling.
RIS CATEGORY : Accepted
TYPE OF RIS : micro
GEOLOGY REFERENCES : 64,79,80,106,393,468A

Val Noana

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DAM NAME : Val Noana
RESERVOIR NAME : Lago di Val Noana
COUNTRY : Italy
RIVER : Noana
LOCATION OF CENTER OF RESERVOIR : 46.07N,11.43E
PROVINCE OR REGION : Trento
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 114 m above ground
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 126. m
LENGTH OF DAM : 128. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 108.00 m
MAXIMUM VOLUME OF RESERVOIR : 11. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 2.2 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Very hard brown limestone with interlayers of white dolomitic limestone
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 106,289
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Valle di Lei

DAM NAME : Valle di Lei
COUNTRY : Switzerland/Italy
RIVER : Reno di Lei
LOCATION OF CENTER OF RESERVOIR : 46.44N,9.44E
PROVINCE OR REGION : Grigioni/Sondrio
DAM TYPE : Concrete arch () gravity
DATE DAM COMPLETED : 1961
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 143 m above ground
ORIENTATION OF RESERVOIR : S
STRUCTURAL HEIGHT OF DAM : 143. m
LENGTH OF DAM : 690. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 125.00 m
MAXIMUM VOLUME OF RESERVOIR : 200. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 8.0 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Gneiss
SITE GEOLOGY : Metamorphic
PREDOMINANT FAULT TYPE : Left-slip
AZIMUTH OF PREDOMINANT FAULTING : NE
MAXIMUM LENGTH OF FAULTS : 95.00 (km) km
DISTANCE TO CLOSEST KNOWN FAULT : 20.0 (km) km
GEOLOGY REFERENCES : 106,289,340B

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Verkhne Svirskoye


DAM NAME : Verkhne Svirskoye
RESERVOIR NAME : Ozero Onezhskoye
COUNTRY : USSR
RIVER : Svir
LOCATION OF CENTER OF RESERVOIR : 61.50N,35.75E
PROVINCE OR REGION : Leningrad
DAM TYPE : Earth () buttress and gravity spillway section
DATE DAM COMPLETED : 1952
DATE OF START OF FILLING : Began Dec-1951
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam increases existing lake.
STRUCTURAL HEIGHT OF DAM : 32. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 30.40 m
MAXIMUM VOLUME OF RESERVOIR : 17500. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 235.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Alluvial deposits up to 10 m thick overlying Devonian shale
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Devonian
GEOLOGY REFERENCES : 106,330A
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Verkhnetulomskiy (Tuloma)


DAM NAME : Verkhnetulomskiy (Tuloma)
RESERVOIR NAME : Ozero Notozero (Nuortti)
COUNTRY : USSR
RIVER : Tuloma
LOCATION OF CENTER OF RESERVOIR : 68.54N,31.00E
LOCATION OF DAM : 68.64N,31.13E
PROVINCE OR REGION : Murmansk
DAM TYPE : Earth () and rock fill, concrete gravity spillway section
DATE DAM COMPLETED : 1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 50. (m) above lowest foundation
MAXIMUM DEPTH OF RESERVOIR : 42.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 42.00 m
MAXIMUM VOLUME OF RESERVOIR : 11500. m3x10E6
SURFACE AREA OF RESERVOIR : 745.00 km2
LONGEST DIMENSION OF RESERVOIR : 88.0 km
NOTES ON REGIONAL GEOLOGY : Archaean and Proterozoic rocks in glaciated region, with Quaternary cover of morainal soils, alluvial
deposits, peats
AGE OF REGIONAL GEOLOGY : Precambrian
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Tectonic depression in river valley, filled by moraine deposits
AGE OF SITE GEOLOGY : Precambrian
GEOLOGY REFERENCES : 31,106,452
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Vidra-Lotru


DAM NAME : Vidra-Lotru
RESERVOIR NAME : Lake Vidra
COUNTRY : Romania
RIVER : Lotru
LOCATION OF CENTER OF RESERVOIR : 45.43N,23.70E
PROVINCE OR REGION : Vilcea
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : W
STRUCTURAL HEIGHT OF DAM : 118. (m) m above lowest foundation
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 106.20 m
MAXIMUM VOLUME OF RESERVOIR : 340. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 107,108,166
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Vidraru

DAM NAME : Vidraru
RESERVOIR NAME : Vidraru
COUNTRY : Romania
RIVER : Arges
LOCATION OF CENTER OF RESERVOIR : 45.46N,24.61E
PROVINCE OR REGION : Arges
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1965
DATE OF START OF FILLING : filling began 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : 158 m above ground
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 166. (m) above foundation
LENGTH OF DAM : 305. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 136.00 m
MAXIMUM VOLUME OF RESERVOIR : 465. m3x10E6
SURFACE AREA OF RESERVOIR : 8.65 km2
LONGEST DIMENSION OF RESERVOIR : 15.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 106,166,368

Villa Gargnano

DAM NAME : Villa Gargnano

RESERVOIR NAME : Lago di Valvestino

COUNTRY : Italy

RIVER : Toscolano

LOCATION OF CENTER OF RESERVOIR : 45.72N,10.62E

PROVINCE OR REGION : Brescia

DAM TYPE : Concrete arch

DATE DAM COMPLETED : 1962

EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower

NOTES ON DAM : Dam height 116 m above ground

ORIENTATION OF RESERVOIR : N

STRUCTURAL HEIGHT OF DAM : 124. m

LENGTH OF DAM : 285. m

RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 106.00 m

MAXIMUM VOLUME OF RESERVOIR : 52. m3x10E6

LONGEST DIMENSION OF RESERVOIR : 4.4 km

NOTES ON REGIONAL GEOLOGY : Dolomites - Mesozoic sediments and metasediments; Triassic dolomites thrust over Jura-Cretaceous flysch deposits.

REGIONAL GEOLOGY : Carbonate

AGE OF REGIONAL GEOLOGY : Triassic

TECTONIC PROVINCE : Alps

REGIONAL STRESS REGIME : Compressional

EVIDENCE FOR REGIONAL STRESS REGIME : tectonics

CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium

NOTES ON SITE GEOLOGY : Dam and reservoir founded on Triassic dolomite

SITE GEOLOGY : Carbonate

AGE OF SITE GEOLOGY : Triassic

PREDOMINANT FAULT TYPE : Thrust

AZIMUTH OF PREDOMINANT FAULTING : NE

MAXIMUM LENGTH OF FAULTS : 25.00 (km) km

DOMINANT SIDE UP : NW

LOCATION OF RESERVOIR IN RELATION TO FAULTS : Fault along or near NE border of lake; upthrown block

GEOLOGY REFERENCES : 106,440A,440B

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Vilyui


DAM NAME : Vilyui
COUNTRY : USSR
RIVER : Vilyui
PROVINCE OR REGION : Yakutsk
DAM TYPE : Earth () and rock fill
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 75. m
LENGTH OF DAM : 700. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 71.25 m
MAXIMUM VOLUME OF RESERVOIR : 35880. m3x10E6
SURFACE AREA OF RESERVOIR : 2010.00 km2
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Quaternary alluvium up to 3 m thick underlain by diabase
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,152,330A
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Volga 22nd Congress

DAM NAME : Volga 22nd Congress
RESERVOIR NAME : Volgogradskoye Vdkhr.
COUNTRY : USSR
RIVER : Volga
LOCATION OF CENTER OF RESERVOIR : 50.44N, 45.88E
LOCATION OF DAM : 48.88N, 44.66E
PROVINCE OR REGION : Volgograd
DAM TYPE : Earth () buttress and gravity spillway section
DATE DAM COMPLETED : 1958
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Hydropower () is principal use
STRUCTURAL HEIGHT OF DAM : 44. m
LENGTH OF DAM : 3974. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 41.80 m
MAXIMUM VOLUME OF RESERVOIR : 33500. m3x10E6
SURFACE AREA OF RESERVOIR : 3160.00 km2
LONGEST DIMENSION OF RESERVOIR : 390.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Sandy and clayey alluvium. Bedrock fault on left bank; western side of valley slightly elevated, consists of interstratified, weakly cemented siltstones, argillites, and arenaceous silts. Lower eastern (left) section Quaternary alluvium up to 20 m thick, overlying Maykop clays and Yergeninskiy sands
SITE GEOLOGY : Fine clastic
GEOLOGY REFERENCES : 106, 152, 306, 330A

Volga Lenin

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DAM NAME : Volga Lenin
RESERVOIR NAME : Kuybyshevskoye Vdkhr.
COUNTRY : USSR
RIVER : Volga
LOCATION OF CENTER OF RESERVOIR : 53.67N,49.00E
LOCATION OF DAM : 53.46N,49.48E
PROVINCE OR REGION : Volga
DAM TYPE : Earth () buttress and concrete gravity spillway section.
DATE DAM COMPLETED : 1955
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 45. m
LENGTH OF DAM : 3781. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 42.75 m
MAXIMUM VOLUME OF RESERVOIR : 58000. m3x10E6
SURFACE AREA OF RESERVOIR : 65000.00 km2
LONGEST DIMENSION OF RESERVOIR : 335.0 km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Alluvial sands up to 70 m thick in gorge, fissured limestone and dolomite in abutments
SITE GEOLOGY : Carbonate
GEOLOGY REFERENCES : 106,152,330A
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Volta Grande

DAM NAME : Volta Grande
RESERVOIR NAME : Volta Grande
COUNTRY : Brazil
RIVER : Grande
LOCATION OF CENTER OF RESERVOIR : 20.14S,48.05W
LOCATION OF DAM : 20.03S,48.22W
DAM TYPE : Earth () fill with center concrete gravity
DATE DAM COMPLETED : 1973
DATE OF START OF FILLING : 1973
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : E
STRUCTURAL HEIGHT OF DAM : 33. m
LENGTH OF DAM : 1854. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 31.35 m
MAXIMUM VOLUME OF RESERVOIR : 2300. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 35.0 (km) km
NOTES ON REGIONAL GEOLOGY : Flood basalts; local sandstone deposits.
REGIONAL GEOLOGY : Volcanic
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Flood basalts.
SITE GEOLOGY : Volcanic
DATE OF FIRST SUSPECTED RIS EVENT : 24-Feb-1974
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Earthquake occurred under Porto Colombia as Volta Grande was being impounded immediately upstream.
GENERAL NOTES : The reported 24 Feb. '74 earthquake was not reported to ISC of NOAA.
RIS CATEGORY : Accepted () (weak case; see Porto Colombia)
TYPE OF RIS : macro
GEOLOGY REFERENCES : 67,107,108,200,393

**Vouglans**

DAM NAME : Vouglans
COUNTRY : France
RIVER : Ain
LOCATION OF CENTER OF RESERVOIR : 46.42N,5.68E
LOCATION OF DAM : 46.41N,5.67E
PROVINCE OR REGION : Jura
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1968
DATE OF START OF FILLING : 1968
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam heigh of 103 m above ground
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 130. m
LENGTH OF DAM : 425. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 112.00 m
MAXIMUM VOLUME OF RESERVOIR : 605. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 6.5 km
TECTONIC PROVINCE : Jura Mountains
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism (), tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Limestone, with vertical fissures, overlain by 25 to 40 m alluvium. Karstitic limestone in reservoir vicinity.
SITE GEOLOGY : Carbonate
NOTES ON FAULTING : Faults bound the depression in which dam and reservoir are located.
DATE OF FIRST SUSPECTED RIS EVENT : 21-Jun-1971
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 4.4 (ISC)
DATE OF LARGEST SUSPECTED RIS EVENT : 21-Jun-1971
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Increase in macroseismicity near the reservoir occurred after the reservoir was emptied in March 1971 and refilled in June 1971, three years after the first impoundment began.
GENERAL NOTES : Data reliability is low. Few data were obtained.
RIS CATEGORY : Accepted
TYPE OF RIS : macro
GEOLOGY REFERENCES : 64,106,146,393,394

## W.A.C. Bennett (Portage Mountain)

DAM NAME : W.A.C. Bennett (Portage Mountain)
RESERVOIR NAME : Williston Lake
COUNTRY : Canada
RIVER : Peace
LOCATION OF CENTER OF RESERVOIR : 56.00N, 123.83W
LOCATION OF DAM : 56.02N, 122.23W
PROVINCE OR REGION : British Columbia
DAM TYPE : Earth () fill
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : T-shaped reservoir
ORIENTATION OF RESERVOIR : NW () and W
STRUCTURAL HEIGHT OF DAM : 183. m
LENGTH OF DAM : 2042. m
MAXIMUM DEPTH OF RESERVOIR : 173.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 173.00 m
MAXIMUM VOLUME OF RESERVOIR : 70309. m3x10E6
SURFACE AREA OF RESERVOIR : 1761.00 km2
LONGEST DIMENSION OF RESERVOIR : 240.0 km
NOTES ON REGIONAL GEOLOGY : Precambrian metasedimentary rock, Paleozoic and Mesozoic sedimentary strata
REGIONAL GEOLOGY : Coarse clastic () and metamorphic
AGE OF REGIONAL GEOLOGY : Mesozoic and Paleozoic
TECTONIC PROVINCE : Rocky Mountain trench
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Cretaceous. Dunlevy series (sandstone and shale) 70 m thick at dam, underlain by Gething series, primarily shale.
SITE GEOLOGY : Fine clastic
AGE OF SITE GEOLOGY : Cretaceous
PREDOMINANT FAULT TYPE : Thrust
AZIMUTH OF PREDOMINANT FAULTING : N30W
DIP OF PREDOMINANT FAULTING : W (); west
GEOLOGY REFERENCES : 106, 127A

Warragamba

DAM NAME : Warragamba

RESERVOIR NAME : Lake Burragorang

COUNTRY : Australia

RIVER : Warragamba

LOCATION OF CENTER OF RESERVOIR : 33.97S, 150.42E

LOCATION OF DAM : 33.90S, 150.60E

PROVINCE OR REGION : New South Wales

DAM TYPE : Gravity

DATE DAM COMPLETED : 1960

DATE OF START OF FILLING : 1960

EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply () and hydropower

NOTES ON DAM : Dam height of 112.5 m above ground; y-shaped reservoir.

ORIENTATION OF RESERVOIR : SW

STRUCTURAL HEIGHT OF DAM : 137. (m) above found.

LENGTH OF DAM : 35. m

MAXIMUM DEPTH OF RESERVOIR : 104.0 m

RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 104.00 m

MAXIMUM VOLUME OF RESERVOIR : 2053. m3x10E6

SURFACE AREA OF RESERVOIR : 75.00 km2

LONGEST DIMENSION OF RESERVOIR : 52.0 km

NOTES ON REGIONAL GEOLOGY : Paleozoic strata from Ordovician to Carboniferous outcrop in reservoir region

REGIONAL GEOLOGY : Coarse clastic

AGE OF REGIONAL GEOLOGY : Paleozoic

REGIONAL STRESS REGIME : Compressional (), E-W horizontal

EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism

CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high

NOTES ON SITE GEOLOGY : Triassic Norrabeen Group and Permian Hawkesbury Sandstone at dam; Permain and Carboniferous in reservoir. Sequence at dam includes Triassic shale, sandstone, and conglomerate. Low-angle fault zone in dam foundation, dipping west, 5.5 m thick gouge zone

SITE GEOLOGY : Coarse clastic

AGE OF SITE GEOLOGY : Carboniferous to Triassic

DATE OF FIRST SUSPECTED RIS EVENT : 6-Mar-1973

MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 5.4 (ISC)

DATE OF LARGEST SUSPECTED RIS EVENT : 9-Mar-1973

NOTES ON SEISMICITY AFTER IMPOUNDMENT : Earthquake sequence at depth of 15 km or greater occurred 13 years after impoundment. Relationship of seismicity to reservoir unclear.

GENERAL NOTES : Data reliability is low. No data obtained on water levels at time of M 5.5 earthquake located under reservoir. Maximum earthquake occurred 13 years after impoundment.

RIS CATEGORY : Questionable

TYPE OF RIS : macro

GEOLOGY REFERENCES : 106, 307, 311, 339, 418, 468B

Xinanjiang (Hsinanchiang)

DAM NAME : Xinanjiang (Hsinanchiang)
RESERVOIR NAME : Xinanjiang (Hsinanchiang)
COUNTRY : China (PRC)
RIVER : Xian Jiang (Hsinanchiang)
LOCATION OF CENTER OF RESERVOIR : 29.58N, 118.97E
LOCATION OF DAM : 29.50N, 119.22E
PROVINCE OR REGION : Zhejiang (Chenchiang)
DAM TYPE : Gravity
DATE DAM COMPLETED : 1960
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
NOTES ON DAM : Reservoir has cross shape
ORIENTATION OF RESERVOIR : NW () and NE
STRUCTURAL HEIGHT OF DAM : 105. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 87.00 m
MAXIMUM VOLUME OF RESERVOIR : 21626. m3x10E6
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
GEOLOGY REFERENCES : 108

```
Xinfengjiang    (Hsinfengkiang)


DAM NAME : Xinfengjiang    (Hsinfengkiang)
RESERVOIR NAME : Xinfengjiang (Hsinfengkiang)
COUNTRY : China (PRC)
RIVER : Xinfeng Jiang (Hsin Chiang)
LOCATION OF CENTER OF RESERVOIR : 23.78N,114.58E
LOCATION OF DAM : 23.73N,114.65E
PROVINCE OR REGION : Guangdong (Kwangtung)
DAM TYPE : Buttress gravity
DATE DAM COMPLETED : 1961
DATE OF START OF FILLING : Oct-1959
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Flood control
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 105. (m) m above lowest foundation
MAXIMUM DEPTH OF RESERVOIR : 80.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 80.00 m
MAXIMUM VOLUME OF RESERVOIR : 13896. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 40.0 km
NOTES ON REGIONAL GEOLOGY : E-W elongate Mesozoic granitic pluton. Upper Paleozoic to Upper Mesozoic sediments north and south of
reservoir. Tertiary clastic red beds south of dam. E-W folds and faults, NE-SW thrust faults dipping SE.
REGIONAL GEOLOGY : Batholithic
AGE OF REGIONAL GEOLOGY : Mesozoic
REGIONAL STRESS REGIME : Shear (); maximum compression NW-SE
EVIDENCE FOR REGIONAL STRESS REGIME : focal mechanism
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : high
NOTES ON SITE GEOLOGY : Dam underlain by granite; reservoir primarily by granite as well as Mesozoic flysch and clastic red-bed
units.
SITE GEOLOGY : Batholithic
AGE OF SITE GEOLOGY : Mesozoic
PREDOMINANT FAULT TYPE : Left-slip
AZIMUTH OF PREDOMINANT FAULTING : NE
DIP OF PREDOMINANT FAULTING : N70E () deg dip
MAXIMUM LENGTH OF FAULTS : 600.00 (km) km long (Hoyuan fault)
NAME OF CLOSEST KNOWN FAULT : Hoyuan fault
DISTANCE TO CLOSEST KNOWN FAULT : 1.0 (km) km downstream from dam
AGE OF MOST RECENT DISPLACEMENT ON CLOSEST KNOWN FAULT : Holocene
ARE LOCAL FAULTS ACTIVE? : Yes
SEISMICITY ASSOCIATED WITH FAULTS IN LOCAL AREA? : Yes
NOTES ON HYDROLOGY : Groundwater is concentrated in fracture zones in granite batholith. Fault contact with adjacent metamorphic
units and Hoyuan fault form groundwater barriers. Groundwater gradient probably reflects topograpyy except at fault zones.
TYPE OF PERMEABILITY : fracture
DEGREE OF TOPOGRAPHIC RELIEF : High
DATE OF FIRST SUSPECTED RIS EVENT : Nov-1959
MAGNITUDE OR INTENSITY OF LARGEST SUSPECTED RIS EVENT : Mag 6 (Peking)
DATE OF LARGEST SUSPECTED RIS EVENT : 18-Mar-1962
NOTES ON SEISMICITY AFTER IMPOUNDMENT : Increase in macroseismicity three years after impoundment began.  Microseismicity near the
reservoir occurred as filling began, and shows limited relationships to water level fluctuations.
GENERAL NOTES : Data reliability is moderate to high.
RIS CATEGORY : Accepted
TYPE OF  RIS : macro and micro
GEOLOGY REFERENCES : 108,203,226,412,418,469A
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Yagisawa


DAM NAME : Yagisawa
COUNTRY : Japan
RIVER : Tone
LOCATION OF CENTER OF RESERVOIR : 36.93N,139.07E
PROVINCE OR REGION : Gunma
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1967
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Public water supply () and flood control
STRUCTURAL HEIGHT OF DAM : 131. (m) above lowest foundation
LENGTH OF DAM : 402. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 113.00 m
MAXIMUM VOLUME OF RESERVOIR : 204. m3x10E6
SURFACE AREA OF RESERVOIR : 5.67 km2
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : granite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 106,233,470,471
```

```
Yamase          (Yanase)


DAM NAME : Yamase          (Yanase)
COUNTRY : Japan
RIVER : Nahari
LOCATION OF CENTER OF RESERVOIR : 33.89N,134.12E
PROVINCE OR REGION : Kochi
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1965
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
NOTES ON DAM : Dam height 104 m above ground
ORIENTATION OF RESERVOIR : N
STRUCTURAL HEIGHT OF DAM : 115. m
LENGTH OF DAM : 202. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 103.50 m
MAXIMUM VOLUME OF RESERVOIR : 105. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 6.5 km
REGIONAL STRESS REGIME : Shear
EVIDENCE FOR REGIONAL STRESS REGIME : faulting sense
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
GEOLOGY REFERENCES : 106
```

## Yellowtail

DAM NAME : Yellowtail
RESERVOIR NAME : Bighorn Lake
COUNTRY : USA
RIVER : Bighorn
LOCATION OF CENTER OF RESERVOIR : 45.10N, 108.13W
LOCATION OF DAM : 45.20N, 107.95W
PROVINCE OR REGION : Montana
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1966
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Multi-purpose; Irrigation () listed first
NOTES ON DAM : Dam height 151 m above ground
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 160. (m) above foundation
LENGTH OF DAM : 451. m
MAXIMUM DEPTH OF RESERVOIR : 151.0 m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 151.00 m
MAXIMUM VOLUME OF RESERVOIR : 1696. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 115.0 km
REGIONAL STRESS REGIME : Extensional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Carboniferous Madison limestone, gently dipping, predominantly massive, total thickness 224 m at dam site. Upper part includes two zone of well cemented calcareous shale and siltstone.
SITE GEOLOGY : Carbonate
AGE OF SITE GEOLOGY : Carboniferous
DEGREE OF DEFORMATION : shallow dipping
GEOLOGY REFERENCES : 106, 284A

Zeuzier (Tseuzier)

DAM NAME : Zeuzier (Tseuzier)
RESERVOIR NAME : Lac de Zeuzier (Tseuzier)
COUNTRY : Switzerland
RIVER : Lienne
LOCATION OF CENTER OF RESERVOIR : 46.35N, 7.46E
PROVINCE OR REGION : Valais
DAM TYPE : Concrete arch
DATE DAM COMPLETED : 1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : NW
STRUCTURAL HEIGHT OF DAM : 156. (m) m above lowest foundation
LENGTH OF DAM : 280. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 126.00 m
MAXIMUM VOLUME OF RESERVOIR : 50. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 1.3 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Limestone
SITE GEOLOGY : Carbonate
PREDOMINANT FAULT TYPE : Right-slip
DISTANCE TO CLOSEST KNOWN FAULT : 1.0 to 2.0 (km) km
NOTES ON SEISMICITY BEFORE IMPOUNDMENT : Area of historical seismic activity
NOTES ON SEISMICITY AFTER IMPOUNDMENT : 1976 epicenter 5 km from reservoir associated with fault swarm; M 3.6.
GEOLOGY REFERENCES : 106,289

Zevreila

DAM NAME : Zevreila
COUNTRY : Switzerland
RIVER : Valserrhein
LOCATION OF CENTER OF RESERVOIR : 46.57N, 9.11E
PROVINCE OR REGION : Graubunden
DAM TYPE : Rock () fill
DATE DAM COMPLETED : 1957
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
ORIENTATION OF RESERVOIR : SW
STRUCTURAL HEIGHT OF DAM : 151. (m) m above lowest foundation
LENGTH OF DAM : 504. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 135.90 m
MAXIMUM VOLUME OF RESERVOIR : 100. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 5.6 km
TECTONIC PROVINCE : Alps
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : medium
NOTES ON SITE GEOLOGY : Gneiss
SITE GEOLOGY : Metamorphic
GEOLOGY REFERENCES : 106,289

```
Zeya            (Zeyskaya)

DAM NAME : Zeya             (Zeyskaya)
COUNTRY : USSR
RIVER : Zeya
PROVINCE OR REGION : East Siberia
DAM TYPE : Earth () and rock fill buttress with concrete gravity spillway section
DATE DAM COMPLETED : 1975
EXPECTED FLUCTUATIONS BASED ON PRIMARY USE : Hydropower
STRUCTURAL HEIGHT OF DAM : 112. m
LENGTH OF DAM : 714. m
RESERVOIR DEPTH COMPUTED FROM DAM HEIGHT : 100.80 m
MAXIMUM VOLUME OF RESERVOIR : 68400. m3x10E6
LONGEST DIMENSION OF RESERVOIR : 300.0 (km) km
REGIONAL STRESS REGIME : Compressional
EVIDENCE FOR REGIONAL STRESS REGIME : tectonics
CONFIDENCE IN REGIONAL STRESS REGIME EVALUATION : low
NOTES ON SITE GEOLOGY : Alluvium in riverbed up to 13 ft thick, colluvium on slopes up to 26 ft thick, underlain by diorite
SITE GEOLOGY : Batholithic
GEOLOGY REFERENCES : 306,330A
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**Woodward-Clyde Consultants**

# STUDY OF
# RESERVOIR INDUCED SEISMICITY

## APPENDIX B

## EARTHQUAKE CATALOGS FOR SELECTED CASES OF REPORTED RIS

FINAL TECHNICAL REPORT

August 1979

By

Duane R. Packer, Lloyd S. Cluff,
Peter L. Knuepfer and Robert J. Withers

Sponsored By The
U.S. Geological Survey
Contract No. 14-08-0001-16809

WOODWARD-CLYDE CONSULTANTS
Consulting Engineers, Geologists, and Environmental Scientists
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# TITLE PAGE

1. CONTRACT NO.: 14-08-0001-16809
2. NAME OF CONTRACTOR: Woodward-Clyde Consultants
3. CO-PRINCIPAL INVESTIGATORS: Lloyd S. Cluff and
   Duane R. Packer
4. GOVERNMENT TECHNICAL OFFICER: Dr. Jack F. Evernden
5. SHORT TITLE OF WORK: Reservoir Induced Seismicity
6. EFFECTIVE DATE OF CONTRACT: 15 February 1978
7. CONTRACT EXPIRATION DATE: 14 February 1979 extended
   to 14 June 1979
8. AMOUNT OF CONTRACT: $199,433.00
9. DATE REPORT SUBMITTED: August 1979

# APPENDIX B

# EARTHQUAKE CATALOGS FOR SELECTED CASES OF REPORTED RIS

## Table of Contents

## List of Tables

# APPENDIX B

# EARTHQUAKE CATALOGS FOR SELECTED CASES OF REPORTED RIS

## B.1 INTRODUCTION

The accompanying earthquake catalogs have been produced from the Woodward-Clyde Consultants Earthquake Data Bank. The region from which earthquake locations have been selected and other selection parameters are indicated at the beginning of each catalog.

The earthquake epicenter/hypocenter data presented here have been transcribed from one or more of the sources cited on the Source Codes list. Every attempt has been made to reproduce this source material as accurately as possible. Any questionable data should be checked against the original source or through Woodward-Clyde Consultants. Please bring any errors to our attention.

It is important to note that the quality of epicenter locations is not temporally or spatially consistent from source to source, or even within each source. Also, because the data are computerized, all latitudes and longitudes are printed in the catalog to thousandths of a degree (0.001), regardless of how the coordinates were tabulated in the original source. This does not imply that the original coordinates reflect that degree of accuracy. In most cases, the implicit accuracy is obvious from the coordinate. For example, if an original source entry latitude were 23N, it would appear in the catalog as 23.000N.

## B.1.1 Explanation of Earthquake Catalog Column Headings

| | |
|---|---|
| CAT. NO. | Sequential catalog number assigned to each earthquake in each catalog. |
| DATA DAY-MO-YR | Date in Greenwich mean time unless noted otherwise in time column (usually as 'LT' for local time). |
| TIME (GMT) HR-MIN-SEC | Time in Greenwich mean time unless noted otherwise in time column (usually as 'LT' for local time). |
| LAT | Latitude, north or south as noted. When original sources have given the latitude or longitude in degrees, minutes, and seconds, or as fractions of a degree, these have been converted to decimal degrees. Although the catalog presents the coordinates in thousandths of a degree, this does not imply location accuracy to that precision. In many cases the implicit accuracy is discernible from the coordinate. For example, if a latitude were originally reported as 23 1/4 N, the catalog would list it as 23.250N. |
| LONG | Longitude, east or west as noted (see note above). |
| SL | Source of the latitude and longitude if different from the main source (column "S"). Frequently, only a place name is given for an earthquake location in the original data. In many such cases, the coordinates of the place have been assigned to the earthquake by Woodward-Clyde Consultants. The characters 'W', 'W1', or 'W2' are placed in this column to indicate the degree of precision of the place name location, as follows:<br>W nearest hundredth or thousandth degree<br>W1 nearest tenth degree<br>W2 nearest half degree. |
| INTEN (MM) | Maximum intensity, reported on the Modified Mercalli Scale of 1931, unless noted otherwise; for example, 'RF' indicates Rossi-Forel intensity scale. |
| MAG | Earthquake magnitude, usually reported as local Richter, body wave, or surface wave (see "SM" column). |

| | |
|---|---|
| SM | Source of magnitude, if different from the main source (column "S"), or magnitude scale, if known. MB = body wave scale. MS = surface wave scale. ML = local Richter magnitude. N' = magnitude reported by NOAA. |
| H<br>(KM) | Hypocenter depth, in kilometers. |
| DIS<br>(MI) (KM) | Epicentral distance from the site in miles or kilometers, as noted. |
| Q | Epicenter quality indicated as reported in main source. These are not quality judgments assigned by Woodward-Clyde Consultants unless the main source for the event is Woodward-Clyde Consultants. |
| S | Main source for earthquake. For these listings, the source generally is either IS (International Seismological Centre) or NOAA (National Oceanographic and Atmospheric Administration). |
| COMMENT | Source(s) of information from which data entry was compiled, as well as notes on damage and number of stations used in epicentral solution. |

### B.1.2 Reporting of Fractional Earthquake Magnitudes

Many early magnitudes in the NOAA and ISC data files were originally reported as fractions and have been converted to decimal notations. As is the case with coordinate locations, these decimal notations do not imply accuracy to the nearest hundredth of a unit. For example,

| Magnitude originally reported as | Appears as |
|---|---|
| 6 - 6 1/4 | 6.13 |
| 6 1/4 | 6.25 |
| 6 1/4 - 6 1/2 | 6.38 |
| 6 1/2 | 6.50 |
| 6 1/2 - 6 3/4 | 6.63 |
| 6 3/5 | 6.75 |
| 6 3/4 - 7 | 6.88 |

For any other range, the median value is listed.

### B.1.3 Source Codes Used in Accompanying Catalogs

| | |
|---|---|
| ATH | Athens Observatory, Athens, Greece |
| BCIS | Bureau Central International de Seismologie, Strasbourg, France |
| BRK | Seismograph Stations, University of California, Berkeley, California, USA |
| CGS | United States Coast and Geodetic Survey |
| CLL | Collm Berg Observatory, Leipzig, German Democratic Republic |
| COL | College Outpost station, Alaska |
| EBM | Esen Bulak station, Mongolia |
| GUTE | Gutenberg, B., and Richter, C.F., 1954, Seismicity of the earth and associated phenomena: Princeton University Press, Second Edition, 310 p. |
| HRB | Hurbanovo, Czechoslovakia |
| ISC | International Seismological Centre |
| ISS | International Seismological Summary, Kew, England, UK |
| KEW | Kew, England, UK |
| LAO | LASA Array, Montana, USA |
| LIS | Lisbon, Portugal |
| LJU | Ljubljana, Yugoslavia |
| LVV | L'vov, Ukraine, USSR |
| LWI | Lwiro, Zaire |
| MDD | Madrid, Spain |
| MOS | Moscow, USSR |
| NUR | Nurmijarvi, Finland |
| PAL | Lamont-Doherty Geological Observatory, Palisades, New York, USA |

| | |
|---|---|
| PDE | Preliminary Determination of Epicenters, published by the U.S. Coast and Geodetic Survey |
| PEK | Peking, China |
| PRA | Praha (Prague), Czechoslovakia |
| QUE | Quetta, Pakistan |
| ROM | Rome, Italy |
| SHL | Shillong, India |
| SPCL | Skalnate-Pleso, Czechoslovakia |
| STR | Strasbourg, France |
| TIR | Tirana, Albania |
| TUL | Tulsa, Oklahoma, USA |
| UPP | Uppsala, Sweden |
| USCGS | United States Coast and Geodetic Survey |
| UZH | Uzhgorod, Ukraine, USSR |

## B.2 EARTHQUAKE CATALOGS

Earthquake catalogs are presented for Kremasta, Porto Colombia, Almendra, and Sefid Rud reservoirs. The Kremasta catalog lists all earthquakes within three radii (maximum lake dimension) of the center of the reservoir. Table B-2 correlates the month of occurrence of earthquakes with the distance (in radii) from the reservoir center. Earthquakes at Kremasta within three to five radii of the reservoir center are omitted from the catalog because of the large number of events. The Porto Colombia catalog lists the single event within five radii of the reservoir center. The Almendra and Sefid Rud catalogs list all events within five radii of the reservoir centers. These catalogs include both a chronological listing and a listing according to distance from the reservoir center.

# TABLE B-1
# SEARCH PARAMETERS FOR EARTHQUAKE CATALOGS

| | Radius of Search | Maximum Lake Dimension | Location of Center of Reservoir Latitude | Location of Center of Reservoir Longitude | Number of Earthquakes in Catalog |
|---|---|---|---|---|---|
| Kremasta | 140 km | 28 km | 38.90N | 21.53E | 1307 |
| Porto Colombia | 150 km | 30 km | 20.12S | 48.35W | 1 |
| Volta Grande | 175 km | 35 km | 20.14S | 48.05W | 1 |
| Almendra | 162 km | 32.5 km | 41.12N | 5.16E | 11 |
| Sefid Rud | 175 km | 35 km | 36.73N | 49.35E | 64 |

Notes:

[1] Search was conducted within a 140-km-radius around the center of Kremasta Reservoir; only those events within 84 km (three times maximum lake dimension) are listed in catalog because of the large number of events.

[2] Volta Grande catalog is not provided because it lists same event as Porto Colombia catalog.

## TABLE B-2

## EXPLANATION OF KREMASTA CATALOG: CHRONOLOGICAL LISTING OF NUMBERS OF EARTHQUAKES WITHIN VARIOUS RADII OF KREMASTA RESERVOIR

| Year | Month | 0 - 1R[a] | 1R - 2R[b] | 2R - 3R[c] | 0 - 3R[d] |
|---|---|---|---|---|---|
| 1925 | Jul | 0 | 0 | 1 | 1 |
| 1932 | Aug | 0 | 0 | 1 | 1 |
| 1938 | Mar | 0 | 0 | 2 | 2 |
| 1941 | Mar | 0 | 0 | 1 | 1 |
| 1943 | Jul | 0 | 0 | 1 | 1 |
| 1945 | Jan | 0 | 0 | 1 | 1 |
| 1946 | Nov | 0 | 0 | 1 | 1 |
| 1947 | Apr | 0 | 0 | 1 | 1 |
| 1948 | Jan | 0 | 0 | 1 | 1 |
| 1948 | Apr | 0 | 0 | 2 | 2 |
| 1948 | Jun | 0 | 0 | 1 | 1 |
| 1949 | Jun | 0 | 0 | 1 | 1 |
| 1949 | Oct | 0 | 2 | 0 | 2 |
| 1951 | Jan | 0 | 0 | 2 | 2 |
| 1951 | Feb | 0 | 1 | 0 | 1 |
| 1951 | May | 0 | 1 | 1 | 2 |
| 1952 | Apr | 0 | 2 | 0 | 2 |
| 1952 | Aug | 0 | 0 | 1 | 1 |
| 1952 | Oct | 0 | 1 | 0 | 1 |
| 1953 | Mar | 0 | 2 | 1 | 3 |
| 1953 | Aug | 0 | 0 | 18 | 18 |
| 1963 | Sep | 0 | 0 | 5 | 5 |
| 1953 | Oct | 0 | 0 | 7 | 7 |
| 1953 | Nov | 2 | 2 | 1 | 5 |
| 1953 | Dec | 0 | 0 | 2 | 2 |
| 1954 | Jan | 0 | 0 | 1 | 1 |
| 1954 | Apr | 0 | 0 | 3 | 3 |
| 1954 | May | 0 | 0 | 6 | 6 |
| 1954 | Jun | 0 | 0 | 2 | 2 |
| 1954 | Aug | 0 | 0 | 1 | 1 |
| 1954 | Oct | 0 | 1 | 0 | 1 |
| 1954 | Dec | 0 | 0 | 1 | 1 |
| 1955 | Jan | 1 | 4 | 1 | 6 |
| 1955 | Mar | 0 | 0 | 2 | 2 |
| 1955 | May | 0 | 0 | 1 | 1 |
| 1955 | Oct | 0 | 0 | 1 | 1 |
| 1955 | Dec | 0 | 1 | 0 | 1 |
| 1956 | Mar | 0 | 2 | 1 | 3 |
| 1956 | Apr | 0 | 0 | 1 | 1 |
| 1956 | Dec | 0 | 0 | 2 | 2 |
| 1957 | Jan | 0 | 0 | 1 | 1 |
| 1957 | Mar | 0 | 0 | 2 | 2 |
| 1957 | May | 0 | 0 | 2 | 2 |

TABLE B-2 (continued)

| Year | Month | 0 - 1R | 1R - 2R | 2R - 3R | 0 - 3R |
|---|---|---|---|---|---|
| 1957 | Jun | 0 | 0 | 1 | 1 |
| 1957 | Sep | 1 | 0 | 0 | 1 |
| 1957 | Oct | 0 | 3 | 4 | 7 |
| 1957 | Nov | 1 | 0 | 2 | 3 |
| 1958 | Feb | 0 | 1 | 0 | 1 |
| 1958 | May | 0 | 0 | 3 | 3 |
| 1958 | Aug | 0 | 1 | 0 | 1 |
| 1959 | Jan | 1 | 0 | 0 | 1 |
| 1959 | Apr | 0 | 1 | 0 | 1 |
| 1959 | May | 0 | 0 | 1 | 1 |
| 1959 | Jun | 0 | 1 | 0 | 1 |
| 1960 | Jan | 0 | 1 | 0 | 1 |
| 1960 | Feb | 0 | 2 | 9 | 11 |
| 1960 | Apr | 0 | 0 | 1 | 1 |
| 1960 | May | 0 | 1 | 1 | 2 |
| 1960 | Jun | 0 | 0 | 1 | 1 |
| 1960 | Jul | 0 | 0 | 1 | 1 |
| 1960 | Aug | 0 | 1 | 0 | 1 |
| 1960 | Sep | 0 | 1 | 0 | 1 |
| 1960 | Nov | 0 | 0 | 5 | 5 |
| 1961 | Apr | 0 | 1 | 0 | 1 |
| 1961 | Sep | 1 | 1 | 0 | 2 |
| 1961 | Nov | 0 | 1 | 1 | 2 |
| 9162 | Jan | 0 | 1 | 4 | 5 |
| 1962 | Feb | 0 | 0 | 1 | 1 |
| 1962 | Mar | 1 | 0 | 0 | 1 |
| 1962 | Apr | 0 | 2 | 2 | 4 |
| 1962 | May | 3 | 0 | 4 | 7 |
| 1962 | Jul | 0 | 1 | 3 | 4 |
| 1962 | Aug | 1 | 0 | 0 | 1 |
| 1962 | Sep | 0 | 0 | 1 | 1 |
| 1963 | Jan | 1 | 0 | 0 | 1 |
| 1963 | Feb | 1 | 0 | 0 | 1 |
| 1963 | Mar | 0 | 2 | 2 | 4 |
| 1963 | Apr | 2 | 1 | 1 | 4 |
| 1963 | May | 0 | 0 | 2 | 2 |
| 1963 | Jun | 0 | 0 | 1 | 1 |
| 1963 | Sep | 1 | 0 | 0 | 1 |
| 1963 | Nov | 1 | 4 | 0 | 5 |
| 1964 | Jan | 0 | 1 | 0 | 1 |
| 1964 | Mar | 0 | 2 | 0 | 2 |
| 1964 | May | 0 | 1 | 0 | 1 |
| 1964 | Jun | 1 | 1 | 1 | 3 |
| 1964 | Jul | 0 | 0 | 2 | 2 |
| 1964 | Sep | 0 | 0 | 7 | 7 |
| 1964 | Oct | 1 | 0 | 1 | 2 |
| 1964 | Nov | 0 | 0 | 2 | 2 |
| 1965 | Jan | 0 | 1 | 2 | 3 |
| 1965 | Feb | 0 | 0 | 2 | 2 |

TABLE B-2 (continued)

| Year | Month | 0 - 1R | 1R - 2R | 2R - 3R | 0 - 3R |
|---|---|---|---|---|---|
| 1965 | Mar | 0 | 0 | 1 | 1 |
| 1965 | Apr | 0 | 0 | 1 | 1 |
| 1965 | May | 0 | 0 | 1 | 1 |
| 1965 | Jun | 0 | 0 | 2 | 2 |
| 1965 | Jul | 0 | 1 | 2 | 3 |
| 1965 | Aug | 0 | 1 | 1 | 2 |
| 1965 | Sep | 0 | 2 | 1 | 3 |
| 1965 | Oct | 0 | 0 | 1 | 1 |
| 1965 | Nov | 0 | 0 | 1 | 1 |
| 1965 | Dec | 0 | 0 | 2 | 2 |
| 1966 | Jan | 55 | 21 | 2 | 78 |
| 1966 | Feb | 18 | 50 | 8 | 76 |
| 1966 | Mar | 12 | 10 | 3 | 25 |
| 1966 | Apr | 13 | 13 | 2 | 28 |
| 1966 | May | 11 | 17 | 8 | 36 |
| 1966 | Jun | 5 | 9 |  | 19 |
| 1966 | Jul | 4 | 11 | 4 | 19 |
| 1966 | Aug | 8 | 11 | 14 | 33 |
| 1966 | Sep | 3 | 5 | 1 | 9 |
| 1966 | Oct | 2 | 7 | 5 | 14 |
| 1966 | Nov | 0 | 4 | 4 | 8 |
| 1966 | Dec | 0 | 2 | 5 | 7 |
| 1967 | Jan | 4 | 11 | 4 | 19 |
| 1967 | Feb | 0 | 3 | 0 | 3 |
| 1967 | Mar | 2 | 2 | 1 | 5 |
| 1967 | Apr | 0 | 6 | 2 | 8 |
| 1967 | May | 0 | 4 | 13 | 17 |
| 1967 | Jun | 0 | 3 | 3 | 6 |
| 1967 | Jul | 1 | 0 | 4 | 5 |
| 1967 | Aug | 0 | 1 | 4 | 5 |
| 1967 | Sep | 1 | 2 | 4 | 7 |
| 1967 | Oct | 1 | 3 | 5 | 9 |
| 1967 | Nov | 2 | 0 | 3 | 5 |
| 1967 | Dec | 0 | 2 | 2 | 4 |
| 1968 | Jan | 0 | 0 | 1 | 1 |
| 1968 | Feb | 1 | 2 | 4 | 7 |
| 1968 | Mar | 1 | 5 | 0 | 6 |
| 1968 | Apr | 1 | 1 | 2 | 4 |
| 1968 | May | 1 | 0 | 0 | 1 |
| 1968 | Jul | 0 | 0 | 3 | 3 |
| 1968 | Aug | 1 | 3 | 3 | 7 |
| 1968 | Sep | 0 | 0 | 2 | 2 |
| 1968 | Oct | 1 | 4 | 1 | 6 |
| 1968 | Nov | 0 | 2 | 0 | 2 |
| 1968 | Dec | 4 | 4 | 3 | 11 |
| 1969 | Jan | 1 | 1 | 2 | 4 |
| 1969 | Feb | 0 | 3 | 2 | 5 |
| 1969 | Mar | 1 | 1 | 4 | 6 |
| 1969 | Apr | 2 | 3 | 3 | 8 |

TABLE B-2 (continued)

| Year | Month | 0 - 1R | 1R - 2R | 2R - 3R | 0 - 3R |
|---|---|---|---|---|---|
| 1969 | May | 1 | 5 | 1 | 7 |
| 1969 | Jun | 1 | 1 | 1 | 3 |
| 1969 | Jul | 2 | 3 | 2 | 7 |
| 1969 | Aug | 2 | 1 | 2 | 5 |
| 1969 | Sep | 2 | 2 | 2 | 6 |
| 1969 | Oct | 0 | 0 | 4 | 4 |
| 1969 | Nov | 4 | 2 | 2 | 8 |
| 1969 | Dec | 0 | 2 | 2 | 4 |
| 1970 | Jan | 1 | 3 | 2 | 6 |
| 1970 | Feb | 2 | 1 | 3 | 6 |
| 1970 | Mar | 0 | 0 | 2 | 2 |
| 1970 | Apr | 1 | 2 | 3 | 6 |
| 1970 | May | 0 | 2 | 5 | 7 |
| 1970 | Jun | 1 | 3 | 7 | 11 |
| 1970 | Jul | 1 | 0 | 9 | 10 |
| 1970 | Aug | 2 | 5 | 4 | 11 |
| 1970 | Sep | 1 | 1 | 2 | 4 |
| 1970 | Oct | 1 | 4 | 0 | 5 |
| 1970 | Nov | 1 | 3 | 1 | 5 |
| 1970 | Dec | 0 | 1 | 2 | 3 |
| 1971 | Jan | 1 | 1 | 0 | 2 |
| 1971 | Feb | 0 | 3 | 1 | 4 |
| 1971 | Mar | 1 | 2 | 1 | 4 |
| 1971 | Apr | 1 | 2 | 0 | 3 |
| 1971 | May | 0 | 4 | 3 | 7 |
| 1971 | Jun | 0 | 3 | 2 | 5 |
| 1971 | Jul | 0 | 0 | 1 | 1 |
| 1971 | Aug | 1 | 2 | 0 | 3 |
| 1971 | Sep | 0 | 0 | 2 | 2 |
| 1971 | Oct | 1 | 1 | 1 | 3 |
| 1971 | Dec | 0 | 2 | 2 | 4 |
| 1972 | Jan | 1 | 1 | 1 | 3 |
| 1972 | Feb | 1 | 1 | 1 | 3 |
| 1972 | Mar | 0 | 2 | 6 | 8 |
| 1972 | Apr | 0 | 8 | 4 | 12 |
| 1972 | May | 0 | 3 | 4 | 7 |
| 1972 | Jun | 1 | 3 | 4 | 8 |
| 1972 | Jul | 1 | 6 | 3 | 10 |
| 1972 | Aug | 1 | 2 | 2 | 5 |
| 1972 | Sep | 1 | 6 | 1 | 8 |
| 1972 | Oct | 1 | 2 | 1 | 4 |
| 1972 | Nov | 1 | 6 | 5 | 12 |
| 1972 | Dec | 3 | 1 | 2 | 6 |
| 1973 | Jan | 0 | 4 | 3 | 7 |
| 1973 | Feb | 0 | 1 | 3 | 4 |
| 1973 | Mar | 0 | 2 | 3 | 5 |
| 1973 | Apr | 0 | 0 | 3 | 3 |
| 1973 | May | 1 | 10 | 3 | 14 |
| 1973 | Jun | 0 | 1 | 4 | 5 |

TABLE B-2 (continued)

| Year | Month | 0 - 1R | 1R - 2R | 2R - 3R | 0 - 3R |
|---|---|---|---|---|---|
| 1973 | Jul | 0 | 5 | 5 | 10 |
| 1973 | Aug | 1 | 3 | 1 | 5 |
| 1973 | Sep | 1 | 4 | 4 | 9 |
| 1973 | Oct | 2 | 0 | 2 | 4 |
| 1973 | Nov | 2 | 1 | 3 | 6 |
| 1973 | Dec | 2 | 1 | 1 | 4 |
| 1974 | Jan | 0 | 2 | 5 | 7 |
| 1974 | Feb | 1 | 3 | 1 | 5 |
| 1974 | Mar | 1 | 2 | 1 | 4 |
| 1974 | Apr | 1 | 2 | 3 | 6 |
| 1974 | May | 4 | 3 | 0 | 7 |
| 1974 | Jun | 2 | 2 | 10 | 14 |
| 1974 | Jul | 1 | 1 | 10 | 12 |
| 1974 | Aug | 1 | 0 | 4 | 5 |
| 1974 | Sep | 0 | 1 | 5 | 6 |
| 1974 | Oct | 0 | 4 | 4 | 8 |
| 1974 | Nov | 1 | 3 | 5 | 9 |
| 1974 | Dec | 0 | 3 | 7 | 10 |
| 1975 | Jan | 2 | 4 | 4 | 10 |
| 1975 | Feb | 0 | 1 | 1 | 2 |
| 1975 | Mar | 0 | 2 | 4 | 6 |
| 1975 | Apr | 0 | 2 | 3 | 5 |
| 1975 | May | 0 | 1 | 6 | 7 |
| 1975 | Jun | 1 | 19 | 10 | 30 |
| 1975 | Jul | 2 | 28 | 22 | 52 |
| 1975 | Aug | 1 | 0 | 7 | 8 |
| 1975 | Sep | 0 | 4 | 9 | 13 |
| 1975 | Oct | 0 | 1 | 4 | 5 |
| Cumulative | | 242 | 505 | 560 | 1307 |

Notes:

[a] Number of earthquakes during month within one radius (lake dimension) from center of reservoir.

[b] Number of earthquakes during month between one and two radii from center of reservoir.

[c] Number of earthquakes during month between two and three radii from center of reservoir.

[d] Total number of earthquakes during month within three radii of center of reservoir.

### B.2.2 Porto Columbia Catalog

This catalog lists the one earthquake reported by ISC within 150 km of Porto Colombia reservoir, the center of which is located at 20.12S, 48.35W. This is also the only event within 175 km of Volta Grande reservoir, the center of which is located at 20.14S, 48.05W.

The radius (longest reservoir dimension) for Porto Colombia is 30 km, and that for Volta Grande is 35 km (Figure 2-3).

### B.2.3 Almendara Catalog

This catalog lists all earthquakes reported by ISC within 162 km of the center of Almendra (Tormes) reservoir, which is located at 41.12N, 5.16E. The radius (longest reservoir dimension) is 32.5 km for this reservoir (Figure 2-5).

### B.2.4 Sefid Rud Catalog

This catalog lists all earthquakes reported by ISC within 175 km of the center of Sefid Rud reservoir, which is located at 36.73N, 49.35E. The radius (longest reservoir dimension) is 35 km (Figure 2-8).

# DISTANCE CATALOG, KREMASTA RESERVOIR

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SW | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 31 JAN 1966 | 09:54:58.0 | 38.890N | 21.530E | | | 4.50 | | 6 | 1 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 2 | 8 MAY 1966 | 03:48:50.8 | 38.890N | 21.500E | | | 4.10 | | 83 | 3 | | IS | ORIGINAL DATA SOURCE = ISC<br>27 STATION RECORDINGS USED IN SOLUTION |
| 3 | 3 APR 1966 | 11:36:26.1 | 38.940N | 21.530E | | | 4.80 | | 34 | 4 | | IS | ORIGINAL DATA SOURCE = ISC<br>134 STATION RECORDINGS USED IN SOLUTION |
| 4 | 4 MAY 1966 | 07:38:55.0 | 38.930N | 21.500E | | | 4.30 | | 15 | 4 | | IS | ORIGINAL DATA SOURCE = ISC<br>31 STATION RECORDINGS USED IN SOLUTION |
| 5 | 25 JAN 1969 | 20:58:06.0 | 38.890N | 21.580E | | | | | | 4 | | IS | ORIGINAL DATA SOURCE = ISC<br>29 STATION RECORDINGS USED IN SOLUTION |
| 6 | 28 MAY 1969 | 21:53:55.8 | 38.870N | 21.550E | | | | | 21 | 4 | | IS | ORIGINAL DATA SOURCE = ISC<br>20 STATION RECORDINGS USED IN SOLUTION |
| 7 | 5 APR 1970 | 04:27:14.0 | 38.940N | 21.500E | | | | | | 5 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 8 | 8 MAY 1962 | 03:48:15.0 | 38.900N | 21.600E | | | 4.00 | | | 6 | | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = UZH |
| 9 | 26 JAN 1966 | 14:28:51.0 | 38.900N | 21.600E | | | | | | 6 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 10 | 29 JAN 1966 | 05:38:39.0 | 38.900N | 21.600E | | | | | | 6 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 11 | 30 JAN 1966 | 04:48:28.0 | 38.900N | 21.600E | | | | | | 6 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 12 | 30 JAN 1966 | 17:08:46.0 | 38.900N | 21.600E | | | | | | 6 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 13 | 10 MAR 1968 | 10:04:28.0 | 38.900N | 21.600E | | | | | | 6 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 14 | 25 JUN 1969 | 07:25:48.7 | 38.880N | 21.460E | | | | | 2 | 6 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 15 | 25 NOV 1969 | 10:30:24.0 | 38.900N | 21.600E | | | | | | 6 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |

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CAT.      DATE       TIME(GMT)       LAT      LONG    SL INTEN  MAG SM  H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR  HR-MIN-SEC                              (MM)        (KM)(KM)
-----------------------------------------------------------------------------------------------------------------------------------------

16    26 JAN 1966  13:30:28.0  38.940N  21.470E          -  4.60    46   7   IS ORIGINAL DATA SOURCE =  ISC
                                                                                 36 STATION RECORDINGS USED IN SOLUTION

17     4 MAY 1966  06:36:59.0  38.940N  21.470E             4.90    27   7   IS ORIGINAL DATA SOURCE =  ISC
                                                                                141 STATION RECORDINGS USED IN SOLUTION

18    11 JUN 1966  10:21:55.4  38.840N  21.500E             4.70    43   7   IS ORIGINAL DATA SOURCE =  ISC
                                                                                109 STATION RECORDINGS USED IN SOLUTION

19    18 JAN 1972  01:40:43.8  38.849N  21.585E                          7   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  4 STATION RECORDINGS USED IN SOLUTION

20    18 APR 1966  09:59:22.7  38.820N  21.510E             4.30    39   9   IS ORIGINAL DATA SOURCE =  ISC
                                                                                 41 STATION RECORDINGS USED IN SOLUTION

21    11 AUG 1966  05:04:31.1  38.850N  21.610E                          9   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  5 STATION RECORDINGS USED IN SOLUTION

22     2 APR 1971  11:59:16.8  38.900N  21.429E                          9   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  5 STATION RECORDINGS USED IN SOLUTION

23     1 OCT 1971  02:20:50.6  38.823N  21.497E                          9   IS ORIGINAL DATA SOURCE =  ISC
                                                                                 12 STATION RECORDINGS USED IN SOLUTION

24     8 MAR 1966  18:51:47.5  38.870N  21.420E             4.70    44  10   IS ORIGINAL DATA SOURCE =  ISC
                                                                                 65 STATION RECORDINGS USED IN SOLUTION

25    15 JUL 1966  23:50:12.1  38.900N  21.650E             4.40    34  10   IS ORIGINAL DATA SOURCE =  ISC
                                                                                 40 STATION RECORDINGS USED IN SOLUTION

26    22 OCT 1972  14:36:04.3  38.877N  21.645E                      9  10   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  7 STATION RECORDINGS USED IN SOLUTION

27    30 NOV 1953  13:20:58.0  39.000N  21.500E     IX                  11   IS DATA OBTAINED VIA ISS
                                                                                ORIGINAL DATA SOURCE =  PDE

28    30 NOV 1953  13:21:01.0  39.000N  21.500E     IX      5.37        11   IS DATA OBTAINED VIA BCIS
                                                                                ORIGINAL DATA SOURCE =  PDE
                                                                                MAGNITUDE AUTHORITY =   ATH

29    17 SEP 1957  09:32:24.0  39.000N  21.500E                         11   IS ORIGINAL DATA SOURCE =  BCIS
30    27 NOV 1957  03:08:00.0  39.000N  21.500E             5.47        11   IS DATA OBTAINED VIA BCIS
                                                                                ORIGINAL DATA SOURCE =  MOS
                                                                                MAGNITUDE AUTHORITY =   ATH

31    24 JAN 1959  15:02:18.0  39.000N  21.500E     V                   11   IS ORIGINAL DATA SOURCE =  BCIS
32    24 JAN 1966  04:52:03.0  39.000N  21.500E                         11   IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                      [illegible] STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | CIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 24 JAN 1966 | 17:02:08.5 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 34 | 26 JAN 1966 | 13:49:24.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 35 | 26 JAN 1966 | 21:38:18.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 36 | 26 JAN 1966 | 22:21:30.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 37 | 28 JAN 1966 | 16:13:07.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 38 | 28 JAN 1966 | 18:35:26.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 39 | 30 JAN 1966 | 05:50:09.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 40 | 30 JAN 1966 | 06:47:03.0 | 38.870N | 21.650E | | | 4.60 | | 48 | 11 | | IS | ORIGINAL DATA SOURCE = ISC<br>43 STATION RECORDINGS USED IN SOLUTION |
| 41 | 31 JAN 1966 | 15:14:28.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 42 | 12 FEB 1966 | 13:36:22.2 | 38.840N | 21.430E | | | 4.80 | | 46 | 11 | | IS | ORIGINAL DATA SOURCE = ISC<br>55 STATION RECORDINGS USED IN SOLUTION |
| 43 | 26 FEB 1966 | 02:39:18.3 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 44 | 27 FEB 1966 | 19:39:18.0 | 38.800N | 21.500E | | | | | | 11 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 45 | 13 APR 1966 | 10:46:52.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 46 | 18 APR 1966 | 09:54:50.0 | 39.000N | 21.500E | | | | | | 11 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |

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CAT.     DATE        TIME(GMT)     LAT      LONG    SL INTEN  MAG SM  H  DIS Q S          L O C A T I O N     A N D     C O M M E N T S
NO.  DAY-MO-YEAR   HR-MIN-SEC                          (MM)         (KM)(KM)
-------------------------------------------------------------------------------------------------------------------------------------------
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

47    19 APR 1966  02:42:54.3  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

48    10 MAY 1966  05:40:08.8  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     1 STATION RECORDINGS USED IN SOLUTION

49    14 MAY 1966  15:11:14.2  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

50    15 JUN 1966  01:46:27.5  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

51    22 AUG 1966  19:11:59.0  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

52    31 AUG 1966  01:20:36.6  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

53    18 JAN 1967  09:29:28.0  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

54     9 JUL 1967  00:06:48.0  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

55    10 DEC 1968  11:28:35.6  38.830N  21.440E           4.40       46  11   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    62 STATION RECORDINGS USED IN SOLUTION

56    10 DEC 1968  11:34:30.0  38.800N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

57    17 DEC 1968  03:05:13.0  39.000N  21.500E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     3 STATION RECORDINGS USED IN SOLUTION

58    27 APR 1969  05:12:30.0  39.000N  21.500E           3.20               11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

59     9 SEP 1969  14:13:44.0  38.900N  21.400E                          11   IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 22 SEP 1969 | 02:36:26.0 | 39.000N | 21.500E |  | - | 3.30 |  |  | 11 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 61 | 9 NOV 1969 | 15:15:19.0 | 38.800N | 21.500E |  |  |  |  |  | 11 | I | S | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 62 | 15 NOV 1969 | 09:22:50.0 | 38.800N | 21.500E |  |  |  |  |  | 11 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 63 | 18 AUG 1973 | 21:12:20.6 | 38.896N | 21.407E |  |  |  |  | 4 | 11 | I | S | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 64 | 11 MAY 1974 | 11:55:12.4 | 38.906N | 21.401E |  |  |  |  |  | 11 | I | S | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 65 | 10 AUG 1970 | 13:19:38.0 | 38.940N | 21.660E |  |  |  |  |  | 12 | I | S | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 66 | 24 JAN 1966 | 04:53:28.0 | 39.000N | 21.600E |  |  |  |  |  | 13 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 67 | 25 JAN 1966 | 02:12:50.0 | 39.000N | 21.600E |  |  |  |  |  | 13 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 68 | 25 JAN 1966 | 20:28:56.0 | 38.800N | 21.600E |  |  |  |  |  | 13 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 69 | 27 JAN 1966 | 16:43:25.0 | 39.000N | 21.600E |  |  |  |  |  | 13 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 70 | 31 JAN 1966 | 13:28:12.0 | 39.000N | 21.600E |  |  |  |  |  | 13 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 71 | 31 JAN 1966 | 14:10:30.0 | 39.000N | 21.600E |  |  |  |  |  | 13 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 72 | 14 FEB 1966 | 20:16:58.0 | 38.820N | 21.420E |  |  | 4.40 |  | 59 | 13 | I | S | ORIGINAL DATA SOURCE = ISC<br>52 STATION RECORDINGS USED IN SOLUTION |
| 73 | 26 MAR 1966 | 20:17:34.1 | 38.940N | 21.670E |  |  | 4.30 |  | 47 | 13 | I | S | ORIGINAL DATA SOURCE = ISC<br>30 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 74 | 12 JUL 1969 | 00:19:37.9 | 38.800N | 21.460E | | - | | | 33 | 13 | IS | ORIGINAL DATA SOURCE = ISC<br>28 STATION RECORDINGS USED IN SOLUTION |
| 75 | 20 JUN 1970 | 12:21:46.0 | 38.800N | 21.600E | | | | | | 13 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 76 | 23 NOV 1973 | 17:09:44.0 | 39.000N | 21.600E | | | | | | 13 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 77 | 4 FEB 1974 | 00:48:45.0 | 39.000N | 21.600E | | | | | | 13 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 78 | 4 JUN 1966 | 07:06:20.3 | 38.980N | 21.410E | | | | | 7 | 14 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 79 | 20 JUL 1966 | 10:16:06.0 | 38.830N | 21.390E | | | 4.50 | | 22 | 14 | IS | ORIGINAL DATA SOURCE = ISC<br>64 STATION RECORDINGS USED IN SOLUTION |
| 80 | 17 SEP 1972 | 17:01:51.9 | 38.814N | 21.652E | | | | | | 14 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 81 | 10 NOV 1973 | 11:58:07.8 | 38.864N | 21.376E | | | | | | 14 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 82 | 24 JAN 1966 | 04:48:37.0 | 38.900N | 21.700E | | | | | | 15 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 83 | 25 JAN 1966 | 03:55:54.0 | 38.900N | 21.700E | | | | | | 15 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 84 | 30 JAN 1966 | 23:40:15.0 | 38.900N | 21.700E | | | | | | 15 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 85 | 27 MAY 1966 | 23:14:24.4 | 38.900N | 21.700E | | | | | | 15 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>8 STATION RECORDINGS USED IN SOLUTION |
| 86 | 16 SEP 1966 | 20:02:29.3 | 38.900N | 21.700E | | | | | | 15 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 87 | 17 FEB 1970 | 04:51:10.0 | 38.830N | 21.680E | | | 4.60 | | 22 | 15 | IS | ORIGINAL DATA SOURCE = ISC<br>68 STATION RECORDINGS USED IN SOLUTION |
| 88 | 3 MAR 1971 | 22:41:36.1 | 38.776N | 21.464E | | | | | 8 | 15 | IS | ORIGINAL DATA SOURCE = ISC<br>[illegible] STATION RECORDINGS USED IN SOLUTION |

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CAT.      DATE        TIME(GMT)       LAT       LONG     SL INTEN  MAG SM   H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR   HR-MIN-SEC                              (MM)           (KM)(KM)
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89      4 AUG 1971  01:48:21.8  38.856N   21.366E          -                     15    IS ORIGINAL DATA SOURCE =  ISC
                                                                                           5 STATION RECORDINGS USED IN SOLUTION

90     16 MAY 1974  05:16:23.8  38.979N   21.391E                                15    IS ORIGINAL DATA SOURCE =  ISC
                                                                                           6 STATION RECORDINGS USED IN SOLUTION

91     19 JAN 1966  07:26:52.3  38.860N   21.350E                                16    IS ORIGINAL DATA SOURCE =  ISC
                                                                                           7 STATION RECORDINGS USED IN SOLUTION

92     10 FEB 1966  13:21:45.9  38.950N   21.700E                   4.40     39  16    IS ORIGINAL DATA SOURCE =  ISC
                                                                                          31 STATION RECORDINGS USED IN SOLUTION

93     17 FEB 1966  07:37:45.0  39.030N   21.600E                   4.30     25  16    IS ORIGINAL DATA SOURCE =  ISC
                                                                                          18 STATION RECORDINGS USED IN SOLUTION

94     15 MAR 1966  10:46:11.0  38.800N   21.400E                                16    IS ORIGINAL DATA SOURCE =  ISC
                                                                                          11 STATION RECORDINGS USED IN SOLUTION

95     18 APR 1966  08:37:08.0  39.000N   21.400E                   4.30      1  16    IS ORIGINAL DATA SOURCE =  ISC
                                                                                          14 STATION RECORDINGS USED IN SOLUTION

96     21 JUL 1966  03:56:50.5  38.810N   21.380E                                16    IS ORIGINAL DATA SOURCE =  ISC
                                                                                           7 STATION RECORDINGS USED IN SOLUTION

97     14 SEP 1966  14:42:45.0  38.800N   21.400E                                16    IS ORIGINAL DATA SOURCE =  ISC
                                                                                           6 STATION RECORDINGS USED IN SOLUTION

98     15 AUG 1969  13:50:47.0  38.800N   21.400E                                16    IS DATA OBTAINED VIA ISC
                                                                                        ORIGINAL DATA SOURCE =  ATH
                                                                                           3 STATION RECORDINGS USED IN SOLUTION

99     18 DEC 1973  06:56:54.0  39.000N   21.400E                                16    IS DATA OBTAINED VIA ISC
                                                                                        ORIGINAL DATA SOURCE =  ATH
                                                                                           0 STATION RECORDINGS USED IN SOLUTION

100    12 JUN 1964  04:09:43.0  38.750N   21.500E                                17    IS DATA OBTAINED VIA ISC
                                                                                        ORIGINAL DATA SOURCE =  ATH
                                                                                           5 STATION RECORDINGS USED IN SOLUTION

101    16 OCT 1964  09:11:16.0  38.750N   21.500E                                17    IS DATA OBTAINED VIA ISC
                                                                                        ORIGINAL DATA SOURCE =  ATH
                                                                                           2 STATION RECORDINGS USED IN SOLUTION

102    11 MAR 1966  20:19:19.8  38.830N   21.700E                            48  17    IS ORIGINAL DATA SOURCE =  ISC
                                                                                          22 STATION RECORDINGS USED IN SOLUTION

103    28 APR 1966  01:54:29.9  38.820N   21.700E                             5  17    IS ORIGINAL DATA SOURCE =  ISC
                                                                                          10 STATION RECORDINGS USED IN SOLUTION

104    18 MAY 1966  12:10:58.2  38.750N   21.500E                                17    IS DATA OBTAINED VIA ISC
                                                                                        ORIGINAL DATA SOURCE =  ATH
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 3 STATION RECORDINGS USED IN SOLUTION |
| 105 | 28 MAY 1966 | 10:15:27.0 | 38.750N | 21.500E | | | | | | 17 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 106 | 15 JUN 1966 | 05:20:54.0 | 38.750N | 21.500E | | | | | | 17 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 107 | 30 OCT 1966 | 02:10:14.0 | 38.750N | 21.580E | | | 4.70 | | 26 | 17 | IS | ORIGINAL DATA SOURCE = ISC<br>72 STATION RECORDINGS USED IN SOLUTION |
| 108 | 24 JAN 1967 | 10:12:16.0 | 38.750N | 21.500E | | | | | | 17 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 109 | 16 OCT 1967 | 16:12:44.0 | 38.750N | 21.500E | | | | | | 17 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 110 | 9 JUL 1969 | 22:26:31.6 | 39.050N | 21.500E | | | | | | 17 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 111 | 25 JUL 1970 | 16:19:22.0 | 38.750N | 21.500E | | | | | | 17 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 112 | 1 JUN 1974 | 08:27:55.1 | 38.912N | 21.332E | | | | | | 17 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 113 | 17 JAN 1975 | 17:38:20.4 | 39.052N | 21.574E | | | | | | 17 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 114 | 27 JAN 1966 | 15:24:11.0 | 39.000N | 21.700E | | | | | | 18 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>1 STATION RECORDINGS USED IN SOLUTION |
| 115 | 27 JAN 1966 | 17:00:55.0 | 39.000N | 21.700E | | | | | | 18 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 116 | 27 JAN 1966 | 20:37:46.0 | 39.000N | 21.700E | | | | | | 18 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 117 | 30 JAN 1966 | 12:13:57.0 | 39.000N | 21.700E | | | | | | 18 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 118 | 2 FEB 1966 | 23:51:36.6 | 38.840N | 21.340E | | | | | | 18 | IS | ORIGINAL DATA SOURCE = ISC<br>[illegible] STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG SM | H (KM) | CIS (KM) | Q | S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 119 | 27 FEB 1966 | 14:43:38.0 | 38.990N | 21.700E | | | | | 18 | I | S | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 120 | 1 MAY 1966 | 15:52:25.0 | 39.000N | 21.700E | | | | | 18 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 121 | 23 JUL 1966 | 05:28:33.2 | 38.930N | 21.730E | | | | 20 | 18 | I | S | ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 122 | 10 MAR 1967 | 19:42:28.5 | 39.000N | 21.700E | | | 3.20 | | 18 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 123 | 13 NOV 1969 | 05:13:29.0 | 38.800N | 21.700E | | | | | 18 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 124 | 23 MAY 1974 | 15:49:50.6 | 39.052N | 21.475E | | | | 20 | 18 | I | S | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 125 | 2 JUN 1974 | 15:09:53.8 | 38.770N | 21.402E | | | | | 18 | I | S | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 126 | 28 NOV 1974 | 16:47:06.3 | 38.786N | 21.379E | | | | | 18 | I | S | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 127 | 12 AUG 1975 | 23:30:05.0 | 39.036N | 21.640E | | | | | 18 | I | S | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 128 | 19 FEB 1966 | 10:22:27.0 | 39.040N | 21.650E | | | 4.50 | 8 | 19 | I | S | ORIGINAL DATA SOURCE = ISC<br>16 STATION RECORDINGS USED IN SOLUTION |
| 129 | 24 JUN 1966 | 22:34:26.1 | 38.730N | 21.530E | | | 4.70 | 34 | 19 | I | S | ORIGINAL DATA SOURCE = ISC<br>99 STATION RECORDINGS USED IN SOLUTION |
| 130 | 24 DEC 1972 | 22:27:54.8 | 38.791N | 21.706E | | | | 4 | 19 | I | S | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 131 | 28 JAN 1966 | 19:30:27.5 | 38.900N | 21.300E | | | | | 20 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 132 | 6 FEB 1966 | 13:24:38.1 | 39.020N | 21.700E | | | | 36 | 20 | I | S | ORIGINAL DATA SOURCE = ISC<br>24 STATION RECORDINGS USED IN SOLUTION |
| 133 | 1 APR 1966 | 13:15:05.2 | 38.720N | 21.490E | | | 4.70 | 45 | 20 | I | S | ORIGINAL DATA SOURCE = ISC<br>91 STATION RECORDINGS USED IN SOLUTION |
| 134 | 13 FEB 1970 | 14:42:11.3 | 39.080N | 21.550E | | | | | 20 | I | S | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | O S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 135 | 25 JUL 1972 | 01:56:08.5 | 38.728N | 21.475E | | - | 4.70 | | 50 | 20 | IS | ORIGINAL DATA SOURCE = ISC<br>108 STATION RECORDINGS USED IN SOLUTION |
| 136 | 20 SEP 1973 | 21:53:24.5 | 38.718N | 21.533E | | | | | | 20 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 137 | 1 JUL 1975 | 01:44:36.4 | 38.746N | 21.653E | | | | | | 20 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 138 | 19 JUL 1975 | 01:11:08.9 | 38.753N | 21.392E | | | | | | 20 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 139 | 22 JAN 1966 | 05:01:38.1 | 39.080N | 21.600E | | | | | | 21 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 140 | 31 JAN 1970 | 01:26:51.0 | 39.000N | 21.320E | | | | | 18 | 21 | IS | ORIGINAL DATA SOURCE = ISC<br>25 STATION RECORDINGS USED IN SOLUTION |
| 141 | 22 OCT 1970 | 09:34:14.0 | 38.960N | 21.300E | | | | | | 21 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 142 | 13 MAY 1973 | 08:01:55.0 | 38.710N | 21.558E | | | | | | 21 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 143 | 10 DEC 1973 | 02:00:41.4 | 38.888N | 21.291E | | | 3.80 | | 58 | 21 | IS | ORIGINAL DATA SOURCE = ISC<br>27 STATION RECORDINGS USED IN SOLUTION |
| 144 | 20 SEP 1961 | 11:43:06.0 | 39.000N | 21.750E | | V | | | | 22 | IS | ORIGINAL DATA SOURCE = BCIS |
| 145 | 25 AUG 1962 | 07:18:47.0 | 39.000N | 21.750E | | VI | | | | 22 | IS | ORIGINAL DATA SOURCE = BCIS |
| 146 | 30 JAN 1966 | 20:37:55.0 | 39.100N | 21.500E | | | | | | 22 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 147 | 9 FEB 1966 | 06:04:39.4 | 39.100N | 21.500E | | | | | | 22 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 148 | 11 FEB 1966 | 05:40:23.1 | 39.100N | 21.530E | | | | | | 22 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 149 | 17 FEB 1966 | 22:04:09.0 | 39.100N | 21.500E | | | | | | 22 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 150 | 15 MAR 1966 | 21:44:30.0 | 39.000N | 21.750E | | | | | | 22 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 151 | 23 APR 1966 | 11:08:09.9 | 39.010N | 21.320E | | | 4.40 | | 38 | 22 | IS | ORIGINAL DATA SOURCE = ISC<br>41 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 152 | 26 APR 1966 | 05:12:00.1 | 38.710N | 21.480E | | | | | | 22 | I | S | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 153 | 28 APR 1966 | 11:47:33.9 | 38.890N | 21.280E | | | 4.30 | | 53 | 22 | I | S | ORIGINAL DATA SOURCE = ISC<br>48 STATION RECORDINGS USED IN SOLUTION |
| 154 | 27 MAY 1966 | 12:02:47.0 | 39.000N | 21.750E | | | | | | 22 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>1 STATION RECORDINGS USED IN SOLUTION |
| 155 | 19 DEC 1968 | 04:43:42.0 | 39.000N | 21.750E | | | | | | 22 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 156 | 26 SEP 1970 | 06:14:10.5 | 39.050N | 21.700E | | | 4.40 | | 36 | 22 | I | S | ORIGINAL DATA SOURCE = ISC<br>40 STATION RECORDINGS USED IN SOLUTION |
| 157 | 26 OCT 1973 | 20:22:05.6 | 38.873N | 21.282E | | | 3.70 | | 53 | 22 | I | S | ORIGINAL DATA SOURCE = ISC<br>24 STATION RECORDINGS USED IN SOLUTION |
| 158 | 18 MAY 1974 | 20:04:39.6 | 38.898N | 21.780E | | | | | | 22 | I | S | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 159 | 1 MAY 1962 | 11:54:04.0 | 38.700N | 21.600E | | | 4.50 | | | 23 | I | S | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = MOS |
| 160 | 14 APR 1963 | 23:15:20.0 | 38.900N | 21.800E | | | | | | 23 | I | S | ORIGINAL DATA SOURCE = BCIS |
| 161 | 22 JAN 1966 | 06:02:47.0 | 39.100N | 21.600E | | | | | | 23 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 162 | 24 JAN 1966 | 05:00:18.0 | 39.100N | 21.600E | | | | | | 23 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 163 | 26 JAN 1966 | 10:30:13.0 | 39.100N | 21.600E | | | | | | 23 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 164 | 27 JAN 1966 | 11:51:19.0 | 39.100N | 21.600E | | | | | | 23 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 165 | 28 JAN 1966 | 02:30:43.0 | 39.100N | 21.600E | | | | | | 23 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 166 | 28 JAN 1966 | 12:50:22.0 | 39.100N | 21.600E | | | | | | 23 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | LIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 3 STATION RECORDINGS USED IN SOLUTION |
| 167 | 30 JAN 1966 | 06:27:03.0 | 39.100N | 21.600E | | | | | | 23 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 168 | 16 FEB 1966 | 07:12:27.2 | 38.900N | 21.800E | | | | | | 23 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 169 | 13 MAR 1966 | 19:35:55.0 | 38.700N | 21.600E | | | 4.10 | | 65 | 23 | IS | ORIGINAL DATA SOURCE = ISC<br>35 STATION RECORDINGS USED IN SOLUTION |
| 170 | 25 APR 1966 | 23:18:09.1 | 39.000N | 21.300E | | | | | | 23 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 171 | 30 AUG 1966 | 06:00:11.9 | 38.900N | 21.800E | | | | | | 23 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 172 | 9 JAN 1967 | 21:57:45.9 | 38.900N | 21.800E | | | | | | 23 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 173 | 8 SEP 1967 | 09:51:42.8 | 39.080N | 21.400E | | | 4.50 | | 40 | 23 | IS | ORIGINAL DATA SOURCE = ISC<br>65 STATION RECORDINGS USED IN SOLUTION |
| 174 | 11 AUG 1968 | 07:46:04.0 | 39.100N | 21.600E | | | 3.40 | | | 23 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 175 | 14 APR 1969 | 05:11:45.5 | 38.900N | 21.790E | | | 4.50 | | 36 | 23 | IS | ORIGINAL DATA SOURCE = ISC<br>82 STATION RECORDINGS USED IN SOLUTION |
| 176 | 2 FEB 1972 | 21:19:51.7 | 38.777N | 21.317E | | | 4.50 | | 63 | 23 | IS | ORIGINAL DATA SOURCE = ISC<br>72 STATION RECORDINGS USED IN SOLUTION |
| 177 | 23 DEC 1975 | 11:50:26.0 | 38.700N | 21.600E | | | | | | 23 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 178 | 30 JAN 1966 | 03:02:00.1 | 38.940N | 21.800E | | | 4.00 | | 87 | 24 | IS | ORIGINAL DATA SOURCE = ISC<br>21 STATION RECORDINGS USED IN SOLUTION |
| 179 | 25 FEB 1966 | 12:36:25.0 | 39.040N | 21.320E | | | | | 17 | 24 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 180 | 6 MAR 1966 | 06:03:10.5 | 39.060N | 21.720E | | | | | | 24 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 181 | 14 MAR 1966 | 14:08:41.2 | 39.070N | 21.360E | | | 4.60 | | 45 | 24 | IS | ORIGINAL DATA SOURCE = ISC<br>6[illegible] STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 182 | 11 JAN 1967 | 21:49:12.0 | 39.110N | 21.490E | | | | | 11 | 24 | | | IS ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 183 | 16 NOV 1970 | 18:27:40.8 | 38.920N | 21.800E | | | | | | 24 | | | IS ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 184 | 24 MAR 1974 | 10:46:29.2 | 39.095N | 21.400E | | | | | | 24 | | | IS ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 185 | 1 MAR 1962 | 09:49:28.0 | 38.750N | 21.750E | | V | | | | 25 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 186 | 15 JAN 1963 | 21:25:00.0 | 38.700N | 21.400E | | VI | | | | 25 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 187 | 12 APR 1963 | 23:58:55.0 | 39.100N | 21.400E | | | | | | 25 | | | IS DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS |
| 188 | 12 SEP 1963 | 18:29:45.0 | 39.100N | 21.400E | | V | | | | 25 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 189 | 26 JAN 1966 | 17:34:00.0 | 39.100N | 21.400E | | | | | | 25 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 190 | 30 JAN 1966 | 04:29:49.0 | 39.100N | 21.400E | | | | | | 25 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 191 | 17 MAR 1966 | 19:25:22.0 | 38.750N | 21.750E | | | | | | 25 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 192 | 9 APR 1966 | 11:01:11.1 | 39.100N | 21.400E | | | | | | 25 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 193 | 26 MAY 1966 | 06:32:22.0 | 38.700N | 21.400E | | | | | 38 | 25 | | | IS ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 194 | 18 AUG 1966 | 14:00:36.0 | 38.750N | 21.750E | | | | | | 25 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 195 | 4 OCT 1966 | 13:12:37.3 | 38.750N | 21.750E | | | | | | 25 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 196 | 16 NOV 1967 | 02:22:41.0 | 38.750N | 21.750E | | | 3.20 | | | 25 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 197 | 16 NOV 1967 | 05:33:42.0 | 38.750N | 21.750E | | | | | | 25 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 3 STATION RECORDINGS USED IN SOLUTION |
| 198 | 8 FEB 1968 | 13:00:38.0 | 39.100N | 21.400E | | | 3.40 | | | 25 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 199 | 3 MAY 1968 | 03:28:12.0 | 39.060N | 21.330E | | | | | | 25 | IS | ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 200 | 26 OCT 1968 | 03:11:13.0 | 38.750N | 21.750E | | | | | | 25 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 201 | 19 MAR 1969 | 17:05:50.0 | 38.750N | 21.750E | | | | | | 25 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 202 | 24 DEC 1972 | 22:28:01.8 | 38.768N | 21.770E | | | | | | 25 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 203 | 18 OCT 1973 | 04:44:10.8 | 38.742N | 21.317E | | | | | | 25 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 204 | 24 APR 1974 | 01:55:36.0 | 36.700N | 21.400E | | | | | | 25 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 205 | 20 JUL 1974 | 18:10:44.3 | 38.797N | 21.277E | | | | | 8 | 25 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 206 | 31 DEC 1975 | 17:28:21.0 | 38.750N | 21.750E | | | 2.70 | | | 25 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 207 | 23 JAN 1966 | 11:25:07.0 | 39.000N | 21.800E | | | | | | 26 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 208 | 23 JAN 1966 | 19:13:11.0 | 39.000N | 21.800E | | | | | | 26 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 209 | 24 JAN 1966 | 17:54:08.0 | 39.000N | 21.800E | | | | | | 26 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 210 | 28 JAN 1966 | 07:06:15.5 | 39.000N | 21.800E | | | | | | 26 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 211 | 30 JAN 1966 | 14:07:02.0 | 39.000N | 21.800E | | | | | | 26 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |

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CAT.      DATE        TIME(GMT)      LAT       LONG    SL INTEN  MAG SM  H  DIS O S          L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR   HR-MIN-SEC                             (MM)          (KM)(KM)
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                                                                                        2 STATION RECORDINGS USED IN SOLUTION

212   31 JAN 1966   05:05:43.0   39.000N   21.800E                          26    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        2 STATION RECORDINGS USED IN SOLUTION

213    6 FEB 1966   02:09:49.7   39.000N   21.800E                          26    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        3 STATION RECORDINGS USED IN SOLUTION

214   17 AUG 1966   16:16:26.3   38.800N   21.800E                          26    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        3 STATION RECORDINGS USED IN SOLUTION

215   20 APR 1968   02:04:54.0   38.800N   21.800E                          26    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        3 STATION RECORDINGS USED IN SOLUTION

216   29 AUG 1970   16:07:14.0   38.800N   21.800E            3.10          26    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        3 STATION RECORDINGS USED IN SOLUTION

217   20 JUN 1972   11:03:29.0   39.000N   21.800E                          25    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        0 STATION RECORDINGS USED IN SOLUTION

218   11 AUG 1974   12:13:30.1   39.079N   21.730E                          26    IS ORIGINAL DATA SOURCE =  ISC
                                                                                        4 STATION RECORDINGS USED IN SOLUTION

219   22 JAN 1955   20:39:44.0   38.700N   21.700E     VI                   27    IS ORIGINAL DATA SOURCE =  BCIS

220   16 MAY 1962   19:26:36.0   39.000N   21.250E                          27    IS QUALITY =    APRX
                                                                                     ORIGINAL DATA SOURCE =  BCIS

221   24 FEB 1963   22:21:42.0   39.000N   21.250E     V                    27    IS QUALITY =    APRX
                                                                                     ORIGINAL DATA SOURCE =  BCIS

222    3 NOV 1963   15:59:04.6   39.000N   21.250E            4.10          27    IS DATA OBTAINED VIA BCIS
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                     MAGNITUDE AUTHORITY =   CGS

223   15 JAN 1966   21:55:04.0   39.000N   21.250E                          27    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        3 STATION RECORDINGS USED IN SOLUTION

224   21 JAN 1966   09:09:24.0   39.100N   21.700E                          27    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        2 STATION RECORDINGS USED IN SOLUTION

225   21 JAN 1966   15:40:36.0   39.100N   21.700E                          27    IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                        2 STATION RECORDINGS USED IN SOLUTION
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CAT.     DATE       TIME(GMT)      LAT       LONG    SL INTEN  MAG SM  H  DIS Q S          L O C A T I O N     A N D     C O M M E N T S
NO.  DAY-MO-YEAR   HR-MIN-SEC                           (MM)          (KM)(KM)
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226  23 JAN 1966  09:29:20.0  39.100N  21.700E            -                27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  2 STATION RECORDINGS USED IN SOLUTION

227  28 JAN 1966  14:55:24.0  39.100N  21.700E                             27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  1 STATION RECORDINGS USED IN SOLUTION

228  31 JAN 1966  11:28:09.0  39.100N  21.700E                             27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  2 STATION RECORDINGS USED IN SOLUTION

229   7 FEB 1966  20:24:10.0  39.100N  21.700E                             27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  7 STATION RECORDINGS USED IN SOLUTION

230   9 FEB 1966  22:09:05.6  39.100N  21.700E                             27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  3 STATION RECORDINGS USED IN SOLUTION

231   2 MAR 1966  22:49:32.5  39.000N  21.250E                             27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  2 STATION RECORDINGS USED IN SOLUTION

232  12 MAR 1966  17:04:39.0  39.000N  21.250E                             27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  4 STATION RECORDINGS USED IN SOLUTION

233  21 MAR 1966  14:32:31.3  39.100N  21.700E                3.60         27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  4 STATION RECORDINGS USED IN SOLUTION

234   8 AUG 1966  12:34:19.0  38.700N  21.700E                             27  IS ORIGINAL DATA SOURCE =  ISC
                                                                                  5 STATION RECORDINGS USED IN SOLUTION

235  11 AUG 1966  04:34:13.0  38.740N  21.760E                4.60      6  27  IS ORIGINAL DATA SOURCE =  ISC
                                                                                 84 STATION RECORDINGS USED IN SOLUTION

236  15 SEP 1966  12:38:27.0  39.000N  21.250E                             27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  4 STATION RECORDINGS USED IN SOLUTION

237  28 MAR 1967  21:09:24.1  39.000N  21.250E                3.40         27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  3 STATION RECORDINGS USED IN SOLUTION

238  29 AUG 1969  10:43:39.0  39.000N  21.250E                             27  IS DATA OBTAINED VIA ISC
                                                                                ORIGINAL DATA SOURCE =  ATH
                                                                                  3 STATION RECORDINGS USED IN SOLUTION
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CAT.      DATE       TIME(GMT)      LAT       LONG     SL INTEN  MAG SM   H  DIS Q S          L O C A T I O N   A N D   C O M M E N T S
NO.   DAY-MO-YEAR  HR-MIN-SEC                             (MM)           (KM)(KM)
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239   13 NOV 1972  15:09:27.5  39.084N  21.741E        .                19  27  IS ORIGINAL DATA SOURCE =  ISC
                                                                                      15 STATION RECORDINGS USED IN SOLUTION

240   17 JAN 1975  02:44:31.6  38.660N  21.459E                             27  IS ORIGINAL DATA SOURCE =  ISC
                                                                                       4 STATION RECORDINGS USED IN SOLUTION

241   22 JUN 1975  11:50:58.0  38.700N  21.700E                             27  IS DATA OBTAINED VIA ISC
                                                                               ORIGINAL DATA SOURCE =  ATH
                                                                                       0 STATION RECORDINGS USED IN SOLUTION

242   22 MAY 1966  11:15:44.2  38.980N  21.220E                         20  28  IS ORIGINAL DATA SOURCE =  ISC
                                                                                      17 STATION RECORDINGS USED IN SOLUTION

243    4 AUG 1970  17:32:45.3  39.040N  21.800E                         53  28  IS ORIGINAL DATA SOURCE =  ISC
                                                                                      32 STATION RECORDINGS USED IN SOLUTION

244   13 JAN 1971  18:33:05.3  39.092N  21.739E                             28  IS ORIGINAL DATA SOURCE =  ISC
                                                                                      10 STATION RECORDINGS USED IN SOLUTION

245    4 AUG 1972  10:56:27.2  38.686N  21.694E                          7  28  IS ORIGINAL DATA SOURCE =  ISC
                                                                                      17 STATION RECORDINGS USED IN SOLUTION

246   27 AUG 1972  15:56:13.2  39.023N  21.817E                             28  IS ORIGINAL DATA SOURCE =  ISC
                                                                                       6 STATION RECORDINGS USED IN SOLUTION

247   12 DEC 1972  02:32:51.3  38.838N  21.841E                         10  28  IS ORIGINAL DATA SOURCE =  ISC
                                                                                      20 STATION RECORDINGS USED IN SOLUTION

248   15 APR 1974  15:37:01.8  38.660N  21.429E                             28  IS ORIGINAL DATA SOURCE =  ISC
                                                                                       6 STATION RECORDINGS USED IN SOLUTION

249   26 NOV 1961  02:52:48.0  38.750N  21.250E                             29  IS QUALITY =    APRX
                                                                               ORIGINAL DATA SOURCE =  BCIS

250   16 JUL 1965  01:40:34.0  38.750N  21.250E                             29  IS DATA OBTAINED VIA ISC
                                                                               ORIGINAL DATA SOURCE =  ATH
                                                                                       3 STATION RECORDINGS USED IN SOLUTION

251    5 FEB 1966  02:01:45.3  39.100N  21.740E             5.30        16  29  IS ORIGINAL DATA SOURCE =  ISC
                                                                                     261 STATION RECORDINGS USED IN SOLUTION

252   11 FEB 1966  06:49:37.0  39.150N  21.450E             4.40        24  29  IS ORIGINAL DATA SOURCE =  ISC
                                                                                      20 STATION RECORDINGS USED IN SOLUTION

253   15 MAR 1965  12:18:37.0  38.950N  21.200E                         27  29  IS ORIGINAL DATA SOURCE =  ISC
                                                                                       6 STATION RECORDINGS USED IN SOLUTION

254   28 APR 1966  11:55:58.9  38.900N  21.200E                             29  IS DATA OBTAINED VIA ISC
                                                                               ORIGINAL DATA SOURCE =  ATH
                                                                                       4 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 255 | 15 MAY 1966 | 08:29:36.7 | 38.990N | 21.220E | | | | | 51 | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>20 STATION RECORDINGS USED IN SOLUTION |
| 256 | 12 JUN 1967 | 18:12:46.6 | 39.060N | 21.270E | | | 4.60 | | 46 | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>72 STATION RECORDINGS USED IN SOLUTION |
| 257 | 13 FEB 1968 | 22:57:14.0 | 38.750N | 21.250E | | | | | | 29 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 258 | 19 DEC 1968 | 03:53:51.0 | 38.900N | 21.200E | | | | | | 29 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 259 | 22 MAY 1970 | 07:07:34.5 | 39.130N | 21.680E | | | 4.40 | | 44 | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>31 STATION RECORDINGS USED IN SOLUTION |
| 260 | 16 APR 1971 | 11:37:06.8 | 38.759N | 21.251E | | | | | | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 261 | 18 DEC 1971 | 23:27:32.5 | 38.899N | 21.866E | | | | | | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 262 | 8 FEB 1972 | 16:09:56.1 | 39.161N | 21.580E | | | | | | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 263 | 5 JUN 1973 | 03:54:12.0 | 39.024N | 21.825E | | | | | | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 264 | 28 MAR 1974 | 05:26:46.9 | 39.159N | 21.505E | | | | | | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 265 | 4 MAY 1974 | 13:50:06.7 | 39.008N | 21.833E | | | | | | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 266 | 22 JAN 1975 | 16:08:21.0 | 39.001N | 21.843E | | | | | | 29 | | | IS ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 267 | 17 FEB 1966 | 10:41:25.8 | 38.890N | 21.880E | | | 5.10 | | 38 | 30 | | | IS ORIGINAL DATA SOURCE = ISC<br>18 STATION RECORDINGS USED IN SOLUTION |
| 268 | 15 AUG 1966 | 02:16:34.3 | 38.700N | 21.300E | | | | | | 30 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 269 | 11 APR 1967 | 18:56:27.5 | 38.700N | 21.300E | | | | | | 30 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 270 | 28 APR 1967 | 11:32:10.5 | 39.100N | 21.300E | | | 3.50 | | | 30 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |

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CAT.     DATE        TIME(GMT)      LAT       LONG    SL INTEN  MAS SM  H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                              (MM)         (KM)(KM)
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                                                                                     3 STATION RECORDINGS USED IN SOLUTION

271   19 NOV 1970  23:31:49.3  39.070N  21.800E                             30    IS ORIGINAL DATA SOURCE =  ISC
                                                                                    11 STATION RECORDINGS USED IN SOLUTION

272    6 MAR 1971  10:33:33.2  38.683N  21.324E                          92 30    IS ORIGINAL DATA SOURCE =  ISC
                                                                                    15 STATION RECORDINGS USED IN SOLUTION

273   29 JUN 1975  21:33:35.9  39.062N  21.802E                             30    IS ORIGINAL DATA SOURCE =  ISC
                                                                                     8 STATION RECORDINGS USED IN SOLUTION

274   14 AUG 1968  18:23:20.0  39.080N  21.810E                             31    IS ORIGINAL DATA SOURCE =  ISC
                                                                                    29 STATION RECORDINGS USED IN SOLUTION

275   30 JUL 1969  05:20:30.0  39.000N  21.200E                             31    IS ORIGINAL DATA SOURCE =  ISC
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

276   11 SEP 1969  00:09:42.8  38.670N  21.740E                             31    IS ORIGINAL DATA SOURCE =  ISC
                                                                                     7 STATION RECORDINGS USED IN SOLUTION

277   19 APR 1972  03:39:20.0  39.135N  21.723E          4.10            1  31    IS ORIGINAL DATA SOURCE =  ISC
                                                                                    20 STATION RECORDINGS USED IN SOLUTION

278   24 APR 1972  00:48:54.0  39.163N  21.424E                          43 31    IS ORIGINAL DATA SOURCE =  ISC
                                                                                    10 STATION RECORDINGS USED IN SOLUTION

279    3 JAN 1955  01:07:04.0  39.100N  21.800E   VII    5.50               32    IS ORIGINAL DATA SOURCE =  BCIS
                                                                                  MAGNITUDE AUTHORITY =   ATH

280   18 MAR 1963  14:15:11.0  38.900N  21.900E   V                         32    IS ORIGINAL DATA SOURCE =  BCIS

281   24 JAN 1966  09:05:47.0  39.100N  21.800E                             32    IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

282   24 JAN 1966  21:37:26.0  39.100N  21.800E                             32    IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

283   25 JAN 1966  18:27:26.5  39.100N  21.800E                             32    IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

284   26 JAN 1966  07:21:16.0  39.100N  21.800E                             32    IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

285   31 JAN 1966  14:01:31.0  39.100N  21.800E                             32    IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | G S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 286 | 5 FEB 1966 | 02:41:56.5 | 39.100N | 21.800E | | | | | | 32 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 287 | 5 FEB 1966 | 04:56:29.4 | 39.100N | 21.800E | | | | | | 32 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 288 | 5 FEB 1966 | 12:38:44.0 | 38.700N | 21.800E | | | | | 57 | 32 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 289 | 6 FEB 1966 | 00:35:04.4 | 39.100N | 21.800E | | | 3.60 | | | 32 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 290 | 10 FEB 1966 | 19:45:53.7 | 39.100N | 21.800E | | | | | | 32 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 291 | 16 FEB 1966 | 03:06:00.6 | 39.100N | 21.800E | | | | | | 32 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 292 | 28 MAR 1966 | 04:04:46.3 | 38.700N | 21.800E | | | 4.00 | | 71 | 32 | IS | ORIGINAL DATA SOURCE = ISC<br>21 STATION RECORDINGS USED IN SOLUTION |
| 293 | 28 MAR 1967 | 20:53:06.0 | 39.100N | 21.800E | | | | | | 32 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 294 | 13 SEP 1967 | 14:35:10.0 | 38.700N | 21.800E | | | | | | 32 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 295 | 23 DEC 1967 | 08:06:19.0 | 38.700N | 21.800E | | | 3.20 | | | 32 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 296 | 29 MAY 1969 | 21:53:25.4 | 38.940N | 21.900E | | | | | | 32 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 297 | 6 JUN 1969 | 14:38:13.0 | 38.700N | 21.800E | | | | | | 32 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 298 | 3 AUG 1969 | 09:30:35.0 | 38.700N | 21.800E | | | | | | 32 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 299 | 20 DEC 1969 | 14:15:08.0 | 38.700N | 21.800E | | | | | | 32 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 300 | 31 JAN 1970 | 08:04:03.0 | 39.020N | 21.200E | | | | | | 32 | IS | ORIGINAL DATA SOURCE = ISC<br>[illegible] STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE         TIME(GMT)       LAT       LONG     SL INTEN  MAG SM  H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR   HR-MIN-SEC                               (MM)          (KM)(KM)
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301     9 MAY 1971  10:38:16.3  38.609N  21.567E         -              28  32    IS ORIGINAL DATA SOURCE =  ISC
                                                                                     17 STATION RECORDINGS USED IN SOLUTION

302    13 SEP 1972  20:59:48.9  39.133N  21.742E                            32    IS ORIGINAL DATA SOURCE =  ISC
                                                                                     11 STATION RECORDINGS USED IN SOLUTION

303    23 DEC 1975  12:45:46.4  38.685N  21.769E                            32    IS ORIGINAL DATA SOURCE =  ISC
                                                                                      5 STATION RECORDINGS USED IN SOLUTION

304    22 JAN 1966  03:42:36.0  39.200N  21.500E                            33    IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                      2 STATION RECORDINGS USED IN SOLUTION

305    22 JAN 1966  09:53:40.0  39.200N  21.500E                            33    IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                      2 STATION RECORDINGS USED IN SOLUTION

306    31 JAN 1966  12:21:03.0  39.200N  21.500E                            33    IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                      2 STATION RECORDINGS USED IN SOLUTION

307     1 FEB 1966  10:03:39.8  39.200N  21.500E                            33    IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                      4 STATION RECORDINGS USED IN SOLUTION

308    20 FEB 1966  08:44:24.2  39.200N  21.500E                            33    IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                      3 STATION RECORDINGS USED IN SOLUTION

309     3 MAY 1966  12:52:35.0  39.200N  21.500E                            33    IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                      2 STATION RECORDINGS USED IN SOLUTION

310    28 OCT 1968  00:31:43.9  39.180N  21.640E                            33    IS ORIGINAL DATA SOURCE =  ISC
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

311    13 NOV 1969  01:59:39.0  38.600N  21.500E                            33    IS ORIGINAL DATA SOURCE =  ISC
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

312    20 JUN 1971  02:04:07.4  39.061N  21.847E               4.30     35  33    IS ORIGINAL DATA SOURCE =  ISC
                                                                                     40 STATION RECORDINGS USED IN SOLUTION

313    23 MAR 1972  20:05:23.6  39.192N  21.491E                         4  33    IS ORIGINAL DATA SOURCE =  ISC
                                                                                     14 STATION RECORDINGS USED IN SOLUTION

314    11 MAY 1973  09:50:54.5  38.743N  21.202E                            33    IS ORIGINAL DATA SOURCE =  ISC
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

315    10 MAR 1974  16:41:51.0  39.008N  21.179E                            33    IS ORIGINAL DATA SOURCE =  ISC
                                                                                      8 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 316 | 8 APR 1975 | 05:59:14.3 | 39.147N | 21.742E | | | | | 6 | 33 | I | S | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 317 | 22 JAN 1966 | 05:20:42.0 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 318 | 22 JAN 1966 | 05:45:17.0 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 319 | 22 JAN 1966 | 06:51:50.0 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 320 | 22 JAN 1966 | 10:44:50.0 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 321 | 23 JAN 1966 | 10:29:13.0 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 322 | 24 JAN 1966 | 01:19:28.0 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 323 | 25 JAN 1966 | 21:53:42.0 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 324 | 30 JAN 1966 | 22:05:07.0 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 325 | 5 FEB 1966 | 04:53:33.2 | 39.070N | 21.850E | | | | | | 34 | I | S | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 326 | 6 FEB 1966 | 01:52:51.6 | 39.200N | 21.600E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 327 | 6 FEB 1966 | 12:10:54.0 | 39.000N | 21.900E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>1 STATION RECORDINGS USED IN SOLUTION |
| 328 | 28 FEB 1966 | 06:46:28.1 | 39.000N | 21.900E | | | | | | 34 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>6 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE       TIME(GMT)       LAT       LONG    SL INTEN  MAG SM  H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                              (MM)          (KM)(KM)
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329    7 MAR 1968  17:05:00.0  39.200N  21.600E                         59  34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        7 STATION RECORDINGS USED IN SOLUTION

330   16 OCT 1968  16:18:20.0  38.600N  21.600E                             34   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                        3 STATION RECORDINGS USED IN SOLUTION

331   24 DEC 1968  00:17:50.0  38.800N  21.900E            3.20             34   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                        5 STATION RECORDINGS USED IN SOLUTION

332   17 JUL 1969  22:19:59.9  38.810N  21.900E                             34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       12 STATION RECORDINGS USED IN SOLUTION

333   28 APR 1970  04:47:36.0  38.800N  21.900E                             34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        5 STATION RECORDINGS USED IN SOLUTION

334   13 SEP 1970  20:26:51.6  39.110N  21.820E                             34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        4 STATION RECORDINGS USED IN SOLUTION

335   17 JAN 1971  05:59:23.6  39.063N  21.860E            4.30          8  34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       20 STATION RECORDINGS USED IN SOLUTION

336   10 MAY 1971  22:44:04.4  39.158N  21.315E                             34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        6 STATION RECORDINGS USED IN SOLUTION

337   10 JUL 1972  17:12:09.4  38.712N  21.222E                             34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        7 STATION RECORDINGS USED IN SOLUTION

338   24 JUL 1972  01:11:55.7  38.592N  21.491E                             34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        6 STATION RECORDINGS USED IN SOLUTION

339    9 MAY 1973  17:24:38.0  39.000N  21.900E                             34   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                        0 STATION RECORDINGS USED IN SOLUTION

340   13 JAN 1974  02:54:03.8  39.029N  21.176E                             34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       19 STATION RECORDINGS USED IN SOLUTION

341   17 SEP 1975  22:34:38.0  38.602N  21.418E                             34   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        5 STATION RECORDINGS USED IN SOLUTION

342   26 DEC 1975  19:59:14.0  38.600N  21.600E                             34   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                        0 STATION RECORDINGS USED IN SOLUTION

343   21 DEC 1955  21:40:24.0  38.600N  21.400E       V                     35   IS ORIGINAL DATA SOURCE =  BCIS

344   22 JAN 1966  03:33:32.0  39.200N  21.400E                             35   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                        2 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 345 | 7 FEB 1966 | 14:04:45.8 | 39.200N | 21.400E | | | | | | 35 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 346 | 1 MAR 1966 | 04:48:12.3 | 39.200N | 21.400E | | | | | | 35 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION PECORDINGS USED IN SOLUTION |
| 347 | 2 APR 1966 | 06:38:44.8 | 39.200N | 21.400E | | | | | | 35 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 348 | 8 AUG 1966 | 11:07:42.0 | 38.600N | 21.400E | | | | | | 35 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 349 | 20 AUG 1966 | 11:54:07.4 | 38.970N | 21.920E | | | 3.80 | | | 35 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>6 STATION RECORDINGS USED IN SOLUTION |
| 350 | 20 AUG 1966 | 19:49:38.8 | 39.200N | 21.400E | | | | | | 35 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 351 | 18 MAY 1969 | 02:12:04.0 | 38.600N | 21.400E | | | | | | 35 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 352 | 25 MAR 1971 | 19:22:58.0 | 39.038N | 21.899E | | | | | | 35 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 353 | 12 OCT 1972 | 13:00:02.7 | 39.110N | 21.826E | | | | | | 35 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 354 | 3 MAY 1973 | 05:58:16.8 | 38.901N | 21.930E | | | | | 1 | 35 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 355 | 18 JUN 1974 | 06:24:29.7 | 38.766N | 21.898E | | | | | | 35 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 356 | 10 SEP 1975 | 23:45:14.2 | 38.609N | 21.699E | | | | | | 35 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 357 | 3 JAN 1960 | 14:53:46.0 | 38.700N | 21.200E | | | | | | 36 | | IS | ISC EFFECTS CODE = FELT<br>ORIGINAL DATA SOURCE = BCIS |
| 358 | 31 JAN 1966 | 04:30:57.0 | 39.050N | 21.900E | | | 4.50 | | 51 | 36 | | IS | ORIGINAL DATA SOURCE = ISC<br>24 STATION RECORDINGS USED IN SOLUTION |
| 359 | 4 FEB 1966 | 09:12:25.4 | 39.200N | 21.700E | | | | | | 36 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 360 | 5 FEB 1966 | 02:29:53.2 | 39.200N | 21.700E | | | | | | 36 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 361 | 5 FEB 1966 | 09:28:27.5 | 39.200N | 21.700E | | | | | | 36 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 362 | 5 FEB 1966 | 09:47:58.0 | 39.100N | 21.200E | | | | | | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 363 | 6 FEB 1966 | 16:52:36.6 | 39.200N | 21.700E | | | | | | 36 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 364 | 21 JUN 1966 | 20:59:06.5 | 39.200N | 21.700E | | | | | | 36 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 365 | 12 JAN 1967 | 23:54:24.4 | 38.700N | 21.200E | | | | | | 36 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 366 | 8 JUN 1967 | 20:17:45.9 | 38.580N | 21.570E | | | | | | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 367 | 5 OCT 1967 | 05:46:34.0 | 39.100N | 21.200E | | | | | | 36 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 368 | 27 APR 1968 | 03:43:34.0 | 39.100N | 21.200E | | | | | | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 369 | 16 MAY 1969 | 07:27:01.1 | 39.130N | 21.820E | | | 5.00 | | 39 | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>153 STATION RECORDINGS USED IN SOLUTION |
| 370 | 4 AUG 1970 | 18:32:19.0 | 39.200N | 21.680E | | | | | 12 | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 371 | 18 AUG 1970 | 17:40:17.9 | 39.160N | 21.780E | | | 4.50 | | 38 | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>60 STATION RECORDINGS USED IN SOLUTION |
| 372 | 2 OCT 1970 | 20:33:54.0 | 38.600N | 21.700E | | | 3.20 | | | 36 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 373 | 26 NOV 1970 | 17:56:30.9 | 39.140N | 21.810E | | | | | | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 374 | 4 DEC 1970 | 18:02:42.0 | 39.000N | 21.130E | | | | | 24 | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | G S | LOCATION AND COMMENTS |
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| 375 | 19 FEB 1974 | 14:11:05.8 | 38.641N | 21.275E | | | | | 7 | 36 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 376 | 28 APR 1962 | 20:56:29.0 | 38.900N | 21.100E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = BCIS |
| 377 | 3 NOV 1963 | 14:09:16.0 | 38.900N | 21.100E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = BCIS |
| 378 | 3 NOV 1963 | 14:36:02.0 | 38.900N | 21.100E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = BCIS |
| 379 | 3 NOV 1963 | 15:59:12.0 | 38.900N | 21.100E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = BCIS |
| 380 | 24 JUL 1966 | 01:27:39.0 | 38.980N | 21.940E | | | 4.50 | | 15 | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>17 STATION RECORDINGS USED IN SOLUTION |
| 381 | 29 OCT 1966 | 02:39:24.8 | 38.900N | 21.100E | | | 5.80 | | 1 | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>266 STATION RECORDINGS USED IN SOLUTION |
| 382 | 2 NOV 1966 | 19:01:21.8 | 38.900N | 21.100E | | | | | | 37 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 383 | 12 SEP 1967 | 14:46:42.0 | 39.230N | 21.460E | | | 4.70 | | 25 | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>56 STATION RECORDINGS USED IN SOLUTION |
| 384 | 24 OCT 1967 | 06:14:44.7 | 38.910N | 21.960E | | | 4.50 | | 37 | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>41 STATION RECORDINGS USED IN SOLUTION |
| 385 | 19 JUN 1970 | 23:36:10.7 | 39.120N | 21.210E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 386 | 17 MAY 1972 | 13:02:18.6 | 39.123N | 21.206E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 387 | 24 NOV 1972 | 02:50:35.0 | 38.992N | 21.946E | | | | | 16 | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 388 | 15 JAN 1973 | 19:03:30.8 | 38.571N | 21.624E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 389 | 30 JUL 1973 | 19:17:16.2 | 38.912N | 21.959E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 390 | 1 JUL 1975 | 03:43:48.0 | 38.576N | 21.647E | | | | | | 37 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 391 | 5 FEB 1966 | 10:39:56.8 | 39.200N | 21.750E | | | | | | 38 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 392 | 23 SEP 1966 | 23:47:58.1 | 38.600N | 21.730E | | | 4.60 | | 47 | 38 | IS | ORIGINAL DATA SOURCE = ISC<br>31 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
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| 393 | 1 FEB 1974 | 03:24:21.3 | 39.174N | 21.792E | | | | | | 38 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 394 | 4 MAY 1974 | 20:26:06.6 | 39.212N | 21.703E | | | | | | 38 | | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 395 | 2 JUN 1974 | 05:18:57.0 | 38.605N | 21.316E | | | | | | 38 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 396 | 7 OCT 1974 | 08:31:48.0 | 39.244N | 21.494E | | | | | | 38 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 397 | 30 JUN 1975 | 23:59:01.8 | 38.579N | 21.669E | | | | | | 38 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 398 | 1 JUL 1975 | 06:11:49.3 | 38.572N | 21.672E | | | | | | 38 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 399 | 23 OCT 1975 | 03:17:28.1 | 39.234N | 21.635E | | | | | | 38 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 400 | 2 APR 1961 | 15:58:30.0 | 39.250N | 21.500E | | | | | | 39 | | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 401 | 9 JUL 1962 | 17:38:30.0 | 39.250N | 21.500E | | | | | | 39 | | IS | REPORTED FELT INFORMATION<br>QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 402 | 31 JAN 1966 | 10:52:58.0 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 403 | 2 FEB 1966 | 20:05:24.1 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 404 | 5 FEB 1966 | 06:46:41.1 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 405 | 5 FEB 1966 | 10:52:42.2 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 406 | 5 FEB 1966 | 13:11:58.1 | 39.100N | 21.900E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 407 | 12 FEB 1966 | 06:07:33.0 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | G | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 408 | 15 FEB 1966 | 22:48:20.3 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 409 | 16 FEB 1966 | 09:02:20.9 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 410 | 16 FEB 1966 | 14:59:45.4 | 39.100N | 21.900E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 411 | 22 MAR 1966 | 22:52:18.0 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 412 | 5 APR 1966 | 13:57:24.8 | 39.200N | 21.300E | | | 3.80 | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 413 | 7 APR 1966 | 12:58:42.5 | 39.200N | 21.300E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 414 | 13 APR 1966 | 12:18:39.0 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 415 | 18 APR 1966 | 14:26:53.5 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 416 | 25 APR 1966 | 01:12:21.9 | 39.200N | 21.300E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |
| 417 | 4 MAY 1966 | 23:18:08.4 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 418 | 9 MAY 1966 | 08:32:57.5 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 419 | 12 MAY 1966 | 09:12:07.0 | 39.250N | 21.500E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 420 | 21 MAY 1966 | 22:44:56.2 | 39.200N | 21.300E | | | | | | 39 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 421 | 31 MAY 1966 | 00:12:47.0 | 39.250N | 21.500E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>1 STATION RECORDINGS USED IN SOLUTION |
| 422 | 1 JUN 1966 | 21:15:57.7 | 39.250N | 21.500E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 423 | 11 JUN 1966 | 12:39:21.0 | 39.250N | 21.500E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 424 | 12 JUN 1966 | 10:32:42.0 | 39.250N | 21.500E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 425 | 24 JUN 1966 | 01:24:29.3 | 39.200N | 21.300E | | | 3.80 | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 426 | 16 JUL 1966 | 02:32:12.0 | 39.250N | 21.500E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 427 | 28 JUL 1966 | 13:10:08.0 | 38.600N | 21.300E | | | | | 33 | 39 | I | S | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 428 | 31 AUG 1966 | 01:37:25.8 | 39.250N | 21.500E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 429 | 18 SEP 1966 | 13:42:10.4 | 39.100N | 21.900E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 430 | 16 NOV 1966 | 02:57:41.9 | 38.800N | 21.100E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 431 | 22 NOV 1966 | 07:09:31.0 | 39.250N | 21.500E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 432 | 4 JAN 1967 | 07:55:17.5 | 38.700N | 21.900E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>7 STATION RECORDINGS USED IN SOLUTION |
| 433 | 14 JAN 1967 | 10:33:10.5 | 38.700N | 21.900E | | | | | | 39 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 434 | 26 FEB 1967 | 14:41:40.1 | 39.100N | 21.900E | | | | | | 39 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 435 | 9 MAR 1968 | 14:55:36.0 | 38.880N | 21.080E | | | | | 6 | 39 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 436 | 13 MAR 1968 | 15:49:05.0 | 39.250N | 21.500E | | | 3.40 | | | 39 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |
| 437 | 20 AUG 1971 | 16:49:09.0 | 39.200N | 21.300E | | | 3.00 | | | 39 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 438 | 26 JUL 1972 | 09:58:16.0 | 38.800N | 21.100E | | | | | | 39 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 439 | 18 FEB 1973 | 20:25:37.9 | 39.164N | 21.236E | | | | | | 39 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 440 | 15 MAY 1974 | 21:56:53.8 | 39.050N | 21.128E | | | | | | 39 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 441 | 21 JAN 1975 | 08:57:00.5 | 39.030N | 21.948E | | | | | | 39 | IS | ORIGINAL DATA SOURCE = ISC<br>17 STATION RECORDINGS USED IN SOLUTION |
| 442 | 2 JUL 1975 | 01:06:04.7 | 38.596N | 21.752E | | | | | 2 | 39 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 443 | 22 DEC 1975 | 22:34:57.4 | 38.555N | 21.636E | | | | | | 39 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 444 | 5 FEB 1966 | 02:58:01.2 | 39.110N | 21.910E | | | 5.00 | | 50 | 40 | IS | ORIGINAL DATA SOURCE = ISC<br>130 STATION RECORDINGS USED IN SOLUTION |
| 445 | 5 APR 1966 | 08:07:25.0 | 39.040N | 21.960E | | | 4.30 | | 19 | 40 | IS | ORIGINAL DATA SOURCE = ISC<br>21 STATION RECORDINGS USED IN SOLUTION |
| 446 | 21 FEB 1969 | 18:39:57.0 | 39.140N | 21.870E | | | 4.60 | | 33 | 40 | IS | ORIGINAL DATA SOURCE = ISC<br>51 STATION RECORDINGS USED IN SOLUTION |
| 447 | 26 APR 1969 | 23:24:21.1 | 39.250N | 21.620E | | | | | | 40 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 448 | 30 NOV 1970 | 09:49:02.3 | 39.060N | 21.940E | | | 4.50 | | 38 | 40 | IS | ORIGINAL DATA SOURCE = ISC<br>46 STATION RECORDINGS USED IN SOLUTION |
| 449 | 19 SEP 1972 | 12:46:26.1 | 38.653N | 21.200E | | | | | | 40 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 450 | 31 AUG 1973 | 08:22:35.4 | 38.941N | 21.990E | | | | | 6 | 40 | I | S | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 451 | 11 SEP 1973 | 08:26:50.3 | 38.650N | 21.862E | | | | | | 40 | I | S | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 452 | 1 JUL 1975 | 03:12:25.3 | 38.544N | 21.601E | | | | | 7 | 40 | I | S | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 453 | 31 DEC 1975 | 22:54:49.6 | 38.558N | 21.691E | | | 4.30 | | 29 | 40 | I | S | ORIGINAL DATA SOURCE = ISC<br>46 STATION RECORDINGS USED IN SOLUTION |
| 454 | 5 FEB 1966 | 08:28:47.6 | 38.900N | 22.000E | | | | | | 41 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 455 | 9 FEB 1966 | 02:37:13.1 | 39.200N | 21.800E | | | | | | 41 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 456 | 10 MAR 1966 | 02:33:12.8 | 38.910N | 21.060E | | | | | | 41 | I | S | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 457 | 24 JUL 1966 | 01:32:48.9 | 38.900N | 22.000E | | | 4.40 | | | 41 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 458 | 31 MAY 1969 | 07:29:28.0 | 39.200N | 21.800E | | | 3.10 | | | 41 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 459 | 19 DEC 1969 | 23:54:40.5 | 38.920N | 22.000E | | | 4.40 | | 65 | 41 | I | S | ORIGINAL DATA SOURCE = ISC<br>18 STATION RECORDINGS USED IN SOLUTION |
| 460 | 10 APR 1970 | 03:49:51.7 | 39.170N | 21.200E | | | | | | 41 | I | S | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 461 | 21 FEB 1971 | 20:04:15.7 | 39.142N | 21.172E | | | | | 6 | 41 | I | S | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 462 | 11 JUL 1972 | 06:33:24.8 | 39.242N | 21.357E | | | | | | 41 | I | S | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 463 | 27 AUG 1972 | 02:56:29.3 | 38.537N | 21.620E | | | | | | 41 | I | S | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 464 | 24 NOV 1972 | 04:15:14.5 | 39.056N | 21.959E | | | | | | 41 | I | S | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 465 | 15 JAN 1974 | 01:18:58.3 | 39.236N | 21.739E | | | | | | 41 | I | S | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
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| 466 | 2 JUL 1975 | 01:30:30.8 | 38.529N | 21.544E | | | 4.10 | | 46 | 41 | IS | ORIGINAL DATA SOURCE = ISC<br>45 STATION RECORDINGS USED IN SOLUTION |
| 467 | 26 OCT 1975 | 01:09:09.2 | 38.961N | 21.064E | | | | | | 41 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 468 | 23 DEC 1975 | 04:24:39.0 | 38.600N | 21.800E | | | | | | 41 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 469 | 13 OCT 1952 | 16:42:37.0 | 39.000N | 22.000E | | VIII | 4.75 | | | 42 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = ROM<br>MAGNITUDE AUTHORITY = UPP |
| 470 | 3 JAN 1955 | 01:07:02.0 | 39.000N | 22.000E | | | | | | 42 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |
| 471 | 19 MAR 1966 | 10:37:42.4 | 39.000N | 22.000E | | | | | | 42 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 472 | 16 APR 1966 | 18:01:05.0 | 39.000N | 22.000E | | | | | | 42 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 473 | 18 SEP 1966 | 13:43:30.0 | 39.000N | 22.000E | | | | | | 42 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 474 | 19 DEC 1966 | 22:54:30.4 | 38.910N | 21.050E | | | | | | 42 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 475 | 14 MAY 1970 | 10:22:06.0 | 38.800N | 22.000E | | | 3.70 | | | 42 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>8 STATION RECORDINGS USED IN SOLUTION |
| 476 | 3 FEB 1971 | 18:28:12.8 | 38.534N | 21.668E | | | 4.40 | | 40 | 42 | IS | ORIGINAL DATA SOURCE = ISC<br>37 STATION RECORDINGS USED IN SOLUTION |
| 477 | 26 MAY 1971 | 01:16:35.0 | 39.000N | 22.000E | | | 2.80 | | | 42 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 478 | 8 MAR 1972 | 10:25:00.5 | 38.538N | 21.387E | | | | | 10 | 42 | IS | ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |
| 479 | 21 MAY 1972 | 12:25:52.8 | 39.138N | 21.159E | | | | | | 42 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 480 | 25 JUL 1972 | 06:57:39.4 | 38.762N | 21.078E | | | | | | 42 | IS | ORIGINAL DATA SOURCE = ISC<br>[illegible] STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SP | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
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| 481 | 22 JAN 1975 | 13:09:12.5 | 38.983N | 22.006E | | | 3.60 | | 28 | 42 | I | S | ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 482 | 31 DEC 1975 | 13:57:28.1 | 38.545N | 21.702E | | | | | 45 | 42 | I | S | ORIGINAL DATA SOURCE = ISC<br>26 STATION RECORDINGS USED IN SOLUTION |
| 483 | 5 MAY 1960 | 08:17:32.0 | 39.250N | 21.750E | | VI | | | | 43 | I | S | ORIGINAL DATA SOURCE = BCIS |
| 484 | 5 FEB 1966 | 02:11:08.0 | 39.170N | 21.890E | | | 4.90 | | 21 | 43 | I | S | ORIGINAL DATA SOURCE = ISC<br>39 STATION RECORDINGS USED IN SOLUTION |
| 485 | 5 FEB 1966 | 06:37:49.6 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 486 | 9 FEB 1966 | 18:37:56.9 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 487 | 16 FEB 1966 | 13:08:31.0 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 488 | 13 MAR 1966 | 06:49:27.0 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 489 | 17 APR 1966 | 06:59:48.8 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 490 | 4 MAY 1966 | 15:18:25.9 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 491 | 4 MAY 1966 | 17:12:39.3 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 492 | 14 JUL 1966 | 05:18:42.0 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 493 | 18 JAN 1969 | 13:24:16.0 | 39.250N | 21.750E | | | | | | 43 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 494 | 17 FEB 1970 | 15:08:08.7 | 39.120N | 21.120E | | | | | | 43 | I | S | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE        TIME(GMT)      LAT       LONG    SL INTEN  MAG SM  H  DIS Q S           L O C A T I O N     A N D     C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                              (MM)          (KM)(KM)
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495   22 OCT 1970  23:57:12.0  39.160N  21.900E                        12  43    IS ORIGINAL DATA SOURCE =  ISC
                                                                                       14 STATION RECORDINGS USED IN SOLUTION

496   24 JUN 1971  00:53:21.6  38.763N  21.995E                            43    IS ORIGINAL DATA SOURCE =  ISC
                                                                                        4 STATION RECORDINGS USED IN SOLUTION

497    6 MAY 1973  10:56:24.6  38.946N  22.027E                         1  43    IS ORIGINAL DATA SOURCE =  ISC
                                                                                        9 STATION RECORDINGS USED IN SOLUTION

498   16 SEP 1973  12:32:02.9  39.012N  21.061E                            43    IS ORIGINAL DATA SOURCE =  ISC
                                                                                        7 STATION RECORDINGS USED IN SOLUTION

499   28 JAN 1975  01:30:49.5  39.289N  21.514E                            43    IS ORIGINAL DATA SOURCE =  ISC
                                                                                       12 STATION RECORDINGS USED IN SOLUTION

500   29 MAR 1975  15:21:44.8  38.930N  21.038E                            43    IS ORIGINAL DATA SOURCE =  ISC
                                                                                        6 STATION RECORDINGS USED IN SOLUTION

501   25 APR 1975  22:58:22.4  38.704N  21.099E                            43    IS ORIGINAL DATA SOURCE =  ISC
                                                                                        5 STATION RECORDINGS USED IN SOLUTION

502   31 DEC 1975  10:52:57.3  38.638N  21.890E                            43    IS ORIGINAL DATA SOURCE =  ISC
                                                                                       11 STATION RECORDINGS USED IN SOLUTION

503    5 MAY 1956  19:36:13.0  39.300N  21.500E                            44    IS ORIGINAL DATA SOURCE =  BCIS

504   18 OCT 1957  01:50:48.0  38.500N  21.500E                            44    IS DATA OBTAINED VIA USE
                                                                                    REPORTED FELT INFORMATION
                                                                                    ORIGINAL DATA SOURCE =  CGS

505    4 AUG 1958  06:29:02.0  39.200N  21.200E                            44    IS REPORTED FELT INFORMATION
                                                                                    ORIGINAL DATA SOURCE =  BCIS

506   13 SEP 1961  07:34:06.0  38.500N  21.500E     IV                     44    IS QUALITY =    APRX
                                                                                    ORIGINAL DATA SOURCE =  BCIS

507   19 JAN 1962  19:38:00.0  38.500N  21.500E     VII    5.25            44    IS DATA OBTAINED VIA BCIS
                                                                                    ORIGINAL DATA SOURCE =  MOS
                                                                                    MAGNITUDE AUTHORITY =   MOS

508   25 FEB 1966  02:46:30.2  39.200N  21.200E                            44    IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      1 STATION RECORDINGS USED IN SOLUTION

509    3 MAY 1966  13:34:57.3  39.300N  21.500E                            44    IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      2 STATION RECORDINGS USED IN SOLUTION

510   19 JUL 1966  11:14:12.0  38.750N  22.000E            3.40            44    IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      4 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SF | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 511 | 19 JUL 1966 | 12:56:10.3 | 38.750N | 22.000E | | | | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 512 | 20 JUL 1966 | 09:58:13.0 | 38.750N | 22.000E | | | | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 513 | 12 AUG 1966 | 05:21:59.4 | 39.200N | 21.200E | | | | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 514 | 15 SEP 1966 | 02:02:57.8 | 39.200N | 21.200E | | | | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 515 | 21 OCT 1966 | 15:21:06.6 | 38.500N | 21.500E | | | | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 516 | 28 OCT 1966 | 09:52:47.0 | 39.200N | 21.200E | | | | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 517 | 18 APR 1967 | 22:47:13.0 | 38.500N | 21.500E | | | 3.00 | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 518 | 18 APR 1967 | 23:43:36.7 | 38.500N | 21.500E | | | 2.90 | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 519 | 15 AUG 1967 | 11:21:03.0 | 39.200N | 21.200E | | | 3.40 | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 520 | 21 OCT 1967 | 22:35:13.0 | 38.750N | 22.000E | | | 3.30 | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 521 | 21 MAR 1968 | 21:45:03.0 | 38.750N | 22.000E | | | | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 522 | 14 NOV 1968 | 06:04:47.0 | 39.200N | 21.200E | | | | | | 44 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 523 | 25 NOV 1972 | 08:22:37.1 | 39.266N | 21.739E | | | | | | 44 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE       TIME(GMT)     LAT      LONG    SL INTEN  MAG SM  H  DIS Q S           L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                           (MM)           (KM)(KM)
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524    1 JAN 1973  13:43:55.4  38.503N  21.543E                          44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     9 STATION RECORDINGS USED IN SOLUTION

525   10 MAR 1973  09:35:43.7  38.791N  21.044E                     45   44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    19 STATION RECORDINGS USED IN SOLUTION

526   30 JUL 1973  18:46:53.0  38.865N  22.040E                          44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

527   20 JUL 1974  18:21:05.4  38.851N  21.022E                     53   44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    26 STATION RECORDINGS USED IN SOLUTION

528   11 MAY 1975  21:32:19.1  38.977N  21.035E                          44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     7 STATION RECORDINGS USED IN SOLUTION

529   17 JUN 1975  22:05:49.0  39.300N  21.500E                          44   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     0 STATION RECORDINGS USED IN SOLUTION

530   30 JUN 1975  15:51:36.3  38.519N  21.682E                          44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     7 STATION RECORDINGS USED IN SOLUTION

531    2 JUL 1975  01:49:44.0  38.508N  21.518E                          44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    12 STATION RECORDINGS USED IN SOLUTION

532   31 DEC 1975  09:45:47.4  38.524N  21.673E           5.20      19   44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   295 STATION RECORDINGS USED IN SOLUTION

533   31 DEC 1975  10:26:04.8  38.512N  21.442E                     48   44   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    10 STATION RECORDINGS USED IN SOLUTION

534   31 MAR 1964  00:48:45.8  39.300N  21.600E                     33   45   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     9 STATION RECORDINGS USED IN SOLUTION

535    5 FEB 1966  02:17:14.7  39.300N  21.600E                          45   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

536    5 FEB 1966  02:56:15.6  39.190N  21.900E                          45   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    12 STATION RECORDINGS USED IN SOLUTION

537    6 FEB 1966  03:08:04.9  39.300N  21.600E                          45   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     3 STATION RECORDINGS USED IN SOLUTION

538    2 JAN 1967  02:28:21.[illegible]  39.300N  21.600E                          45   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

539   24 FEB 1969  09:08:45.0  39.300N  21.600E                          45   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     9 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | [IS (KM) | O S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 540 | 1 APR 1969 | 19:39:40.4 | 39.030N | 22.020E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 541 | 26 JUN 1970 | 14:13:36.8 | 39.280N | 21.710E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 542 | 16 MAY 1971 | 22:06:11.5 | 39.206N | 21.190E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 543 | 26 APR 1972 | 10:20:23.6 | 38.589N | 21.864E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 544 | 10 JUN 1972 | 06:41:09.5 | 39.164N | 21.135E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 545 | 8 JAN 1973 | 20:09:43.2 | 38.779N | 22.029E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 546 | 2 MAY 1973 | 14:03:39.2 | 38.951N | 22.042E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 547 | 12 MAY 1973 | 01:23:39.6 | 38.830N | 22.044E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 548 | 12 FEB 1975 | 09:55:17.5 | 38.503N | 21.640E | | | | | | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 549 | 30 NOV 1953 | 13:20:58.0 | 38.500N | 21.400E | | IX | | | | 46 | IS | DATA OBTAINED VIA ISS<br>ORIGINAL DATA SOURCE = STR |
| 550 | 30 NOV 1953 | 13:20:58.0 | 38.500N | 21.400E | | IX | | | | 46 | IS | ORIGINAL DATA SOURCE = ISS |
| 551 | 26 MAR 1956 | 22:51:00.0 | 39.200N | 21.900E | | V | | | | 46 | IS | ORIGINAL DATA SOURCE = BCIS |
| 552 | 28 MAR 1956 | 11:39:15.0 | 39.200N | 21.900E | | VI | | | | 46 | IS | QUALITY = REPT<br>ORIGINAL DATA SOURCE = BCIS |
| 553 | 10 JAN 1965 | 08:02:51.7 | 38.700N | 22.000E | | | 4.40 | | 46 | 46 | IS | ORIGINAL DATA SOURCE = ISC<br>18 STATION RECORDINGS USED IN SOLUTION |
| 554 | 4 FEB 1966 | 17:55:45.7 | 39.250N | 21.250E | | | | | | 46 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 555 | 6 FEB 1966 | 18:07:10.3 | 39.300N | 21.400E | | | | | | 46 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 556 | 10 FEB 1966 | 16:33:00.6 | 39.250N | 21.250E | | | | | | 46 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 557 | 15 FEB 1966 | 05:20:19.8 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 558 | 27 FEB 1966 | 01:52:41.9 | 39.300N | 21.400E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 559 | 13 MAR 1966 | 00:16:42.0 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 560 | 4 MAY 1966 | 01:16:33.5 | 39.300N | 21.400E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 561 | 6 MAY 1966 | 08:39:43.0 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 562 | 12 MAY 1966 | 21:58:34.5 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 563 | 14 MAY 1966 | 11:47:42.2 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 564 | 14 JUN 1966 | 20:51:17.0 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 565 | 17 JUN 1966 | 14:39:52.0 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 566 | 17 JUN 1966 | 14:54:46.0 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 567 | 19 JUN 1966 | 06:44:11.2 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 568 | 25 JUL 1966 | 21:14:30.7 | 38.700N | 22.000E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 569 | 17 AUG 1966 | 16:03:57.0 | 39.250N | 21.250E | | | | | | 46 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE        TIME(GMT)      LAT       LONG    SL INTEN  MAG SM   H  LIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR   HR-MIN-SEC                            (MM)          (KM)(KM)
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570   18 AUG 1966  18:18:59.6  39.250N  21.250E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         2 STATION RECORDINGS USED IN SOLUTION

571   25 AUG 1966  04:13:24.0  39.250N  21.250E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         2 STATION RECORDINGS USED IN SOLUTION

572   29 OCT 1966  03:05:20.3  38.900N  21.000E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         7 STATION RECORDINGS USED IN SOLUTION

573    3 JAN 1967  15:31:47.1  39.200N  21.900E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         2 STATION RECORDINGS USED IN SOLUTION

574    9 JAN 1967  20:33:34.5  38.600N  21.900E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         4 STATION RECORDINGS USED IN SOLUTION

575   18 FEB 1967  15:52:43.2  38.700N  22.000E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         4 STATION RECORDINGS USED IN SOLUTION

576   16 MAR 1967  18:51:55.0  38.900N  21.000E                               46    IS ORIGINAL DATA SOURCE =  ISC
                                                                                         5 STATION RECORDINGS USED IN SOLUTION

577    1 MAY 1967  22:46:51.8  39.270N  21.300E                           70  46    IS ORIGINAL DATA SOURCE =  ISC
                                                                                        13 STATION RECORDINGS USED IN SOLUTION

578   23 DEC 1967  11:35:58.0  38.500N  21.400E                3.40           46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         4 STATION RECORDINGS USED IN SOLUTION

579   11 FEB 1968  19:33:10.0  38.700N  22.000E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         3 STATION RECORDINGS USED IN SOLUTION

580   17 DEC 1968  15:37:47.0  39.300N  21.400E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         3 STATION RECORDINGS USED IN SOLUTION

581    6 MAR 1969  17:02:08.0  38.600N  21.900E                               46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
                                                                                         4 STATION RECORDINGS USED IN SOLUTION

582   16 JUL 1969  03:56:45.7  38.950N  21.000E                               46    IS ORIGINAL DATA SOURCE =  ISC
                                                                                         8 STATION RECORDINGS USED IN SOLUTION

583    1 APR 1971  22:11:11.0  39.300N  21.400E                3.40           46    IS DATA OBTAINED VIA ISC
                                                                                       ORIGINAL DATA SOURCE =  ATH
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CAT.     DATE       TIME(GMT)      LAT       LONG    SL INTEN  MAG SP   H  DIS Q S         L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                             (MM)          (KM)(KM)
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                                                                                     0 STATION RECORDINGS USED IN SOLUTION

584   15 OCT 1971  12:36:11.0  38.600N  21.900E              3.20          46   IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                     0 STATION RECORDINGS USED IN SOLUTION

585    8 SEP 1972  21:19:32.9  38.584N  21.869E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     5 STATION RECORDINGS USED IN SOLUTION

586   15 SEP 1972  14:09:34.0  39.300N  21.400E                            46   IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                     0 STATION RECORDINGS USED IN SOLUTION

587   13 NOV 1972  15:18:26.0  39.200N  21.900E                            46   IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  ATH
                                                                                     0 STATION RECORDINGS USED IN SOLUTION

588   21 NOV 1974  11:58:52.6  38.956N  21.009E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     8 STATION RECORDINGS USED IN SOLUTION

589   30 JUN 1975  13:26:54.6  38.489N  21.623E              5.00       3  46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   230 STATION RECORDINGS USED IN SOLUTION

590   30 JUN 1975  19:54:51.1  38.495N  21.653E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     7 STATION RECORDINGS USED IN SOLUTION

591    1 JUL 1975  15:01:47.1  38.545N  21.810E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     9 STATION RECORDINGS USED IN SOLUTION

592    2 JUL 1975  01:53:40.7  38.489N  21.570E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    14 STATION RECORDINGS USED IN SOLUTION

593    3 JUL 1975  09:09:48.4  38.520N  21.727E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     9 STATION RECORDINGS USED IN SOLUTION

594   13 SEP 1975  09:41:05.3  38.761N  21.025E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     5 STATION RECORDINGS USED IN SOLUTION

595   21 DEC 1975  21:58:53.7  38.496N  21.626E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     6 STATION RECORDINGS USED IN SOLUTION

596   22 DEC 1975  01:33:54.6  38.501N  21.653E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     5 STATION RECORDINGS USED IN SOLUTION

597   31 DEC 1975  20:09:11.2  38.512N  21.727E                            46   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    13 STATION RECORDINGS USED IN SOLUTION

598   22 FEB 1960  21:04:09.0  39.000N  21.000E                            47   IS DATA OBTAINED VIA USE
                                                                                   REPORTED FELT INFORMATION
                                                                                   ORIGINAL DATA SOURCE =  CGS
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 599 | 22 FEB 1960 | 21:04:20.0 | 39.000N | 21.000E | | VI | 5.25 | | | 47 | | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = ATH |
| 600 | 2 AUG 1960 | 18:40:30.0 | 38.800N | 21.000E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = BCIS |
| 601 | 25 APR 1962 | 09:49:36.0 | 39.000N | 21.000E | | | | | | 47 | | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 602 | 22 MAR 1963 | 22:27:24.0 | 39.000N | 21.000E | | | | | | 47 | | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 603 | 6 APR 1963 | 09:46:57.0 | 39.000N | 21.000E | | | | | | 47 | | IS | REPORTED FELT INFORMATION<br>QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 604 | 3 NOV. 1963 | 14:07:42.0 | 39.000N | 21.000E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = BCIS |
| 605 | 31 JAN 1966 | 05:49:09.0 | 39.000N | 21.000E | | | | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 606 | 5 FEB 1966 | 18:29:45.3 | 39.300N | 21.700E | | | | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 607 | 11 APR 1966 | 02:02:59.0 | 39.000N | 21.000E | | | | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 608 | 17 APR 1966 | 14:06:40.8 | 39.000N | 21.000E | | | | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 609 | 4 AUG 1966 | 23:58:48.1 | 39.000N | 21.000E | | | | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 610 | 20 NOV 1966 | 14:43:07.0 | 39.000N | 21.000E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 611 | 27 FEB 1967 | 21:22:52.5 | 39.000N | 21.000E | | | | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 612 | 18 APR 1967 | 23:46:15.3 | 38.500N | 21.700E | | | | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 613 | 21 APR 1967 | 02:45:03.3 | 38.800N | 21.000E | | | 3.40 | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | 6 STATION RECORDINGS USED IN SOLUTION |
| 614 | 25 JAN 1970 | 09:57:19.3 | 38.800N | 21.000E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 615 | 1 JUN 1970 | 18:00:25.0 | 39.000N | 21.000E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 616 | 18 OCT 1970 | 02:22:43.0 | 38.800N | 21.000E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 617 | 28 OCT 1970 | 09:29:49.6 | 38.830N | 21.000E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 618 | 29 DEC 1971 | 23:27:29.9 | 39.221N | 21.169E | | | | | 19 | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>47 STATION RECORDINGS USED IN SOLUTION |
| 619 | 15 SEP 1972 | 22:02:03.0 | 39.300N | 21.700E | | | | | | 47 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 620 | 16 MAR 1973 | 23:03:55.6 | 38.942N | 20.990E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 621 | 31 AUG 1973 | 22:41:58.6 | 38.877N | 22.069E | | | | | 4 | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 622 | 30 JUN 1975 | 11:50:21.7 | 38.476N | 21.504E | | | 3.90 | | 22 | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>24 STATION RECORDINGS USED IN SOLUTION |
| 623 | 1 JUL 1975 | 11:58:07.7 | 38.497N | 21.680E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 624 | 3 JUL 1975 | 10:24:14.2 | 38.492N | 21.657E | | | | | | 47 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 625 | 4 MAR 1953 | 15:30:32.0 | 38.500N | 21.750E | | VII | | | | 48 | | IS | DATA OBTAINED VIA ISS<br>ORIGINAL DATA SOURCE = STR |
| 626 | 18 OCT 1957 | 01:50:50.0 | 38.500N | 21.750E | | VII | 5.25 | | | 48 | | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 627 | 18 OCT 1957 | 02:51:37.0 | 38.500N | 21.750E | | V | | | | 48 | | IS | QUALITY = REPT<br>ORIGINAL DATA SOURCE = BCIS |
| 628 | 28 JUN 1959 | 06:02:16.0 | 38.500N | 21.750E | | VI | | | | 48 | | IS | ORIGINAL DATA SOURCE = BCIS |
| 629 | 24 MAR 1964 | 13:19:00.0 | 38.500N | 21.750E | | | | | | 48 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>1 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE        TIME(GMT)      LAT      LONG    SL INTEN  MAG SM   H  (IS G S         L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR   HR-MIN-SEC                           (MM)           (KM)(KM)
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630   18 MAY 1964   18:43:25.0   38.500N  21.750E                            48   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      2 STATION RECORDINGS USED IN SOLUTION

631   26 JUN 1964   10:23:12.0   38.500N  21.750E                            48   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      2 STATION RECORDINGS USED IN SOLUTION

632   29 AUG 1966   20:45:17.6   38.500N  21.750E                            48   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      4 STATION RECORDINGS USED IN SOLUTION

633    5 JAN 1967   17:00:11.4   38.870N  22.080E                      107   48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     25 STATION RECORDINGS USED IN SOLUTION

634    5 JAN 1967   22:49:10.3   38.500N  21.740E                            48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      5 STATION RECORDINGS USED IN SOLUTION

635   11 APR 1972   11:12:13.5   39.294N  21.291E            4.30       39   48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     62 STATION RECORDINGS USED IN SOLUTION

636   22 MAY 1972   09:29:20.8   38.488N  21.364E                            48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      5 STATION RECORDINGS USED IN SOLUTION

637    1 JUL 1972   14:38:28.4   39.231N  21.167E                            48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

638   23 NOV 1972   04:42:14.7   39.294N  21.751E                            48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      8 STATION RECORDINGS USED IN SOLUTION

639    6 SEP 1974   08:55:53.4   38.468N  21.525E                       10   48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     18 STATION RECORDINGS USED IN SOLUTION

640   30 JUN 1975   18:48:55.8   38.479N  21.663E                            48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

641   30 JUN 1975   23:02:20.2   38.470N  21.492E            4.20       39   48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     35 STATION RECORDINGS USED IN SOLUTION

642   30 JUN 1975   23:53:07.1   38.488N  21.700E            4.10       44   48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     46 STATION RECORDINGS USED IN SOLUTION

643    1 JUL 1975   04:38:50.8   38.472N  21.636E                            48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      8 STATION RECORDINGS USED IN SOLUTION

644    5 JUL 1975   10:57:41.6   38.555N  21.872E                            48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

645   16 DEC 1975   14:57:58.9   38.612N  21.938E                            48   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      5 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 646 | 26 DEC 1975 | 04:30:50.8 | 38.489N | 21.711E | | | | | 48 | I | S | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 647 | 31 DEC 1975 | 13:51:20.5 | 38.475N | 21.652E | | | 4.60 | 23 | 48 | I | S | ORIGINAL DATA SOURCE = ISC<br>117 STATION RECORDINGS USED IN SOLUTION |
| 648 | 31 DEC 1975 | 15:25:26.5 | 38.478N | 21.660E | | | | 41 | 48 | I | S | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 649 | 31 DEC 1975 | 17:27:27.7 | 38.488N | 21.382E | | | | 44 | 48 | I | S | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 650 | 31 DEC 1975 | 17:32:58.9 | 38.506N | 21.746E | | | | | 48 | I | S | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 651 | 12 FEB 1951 | 08:24:48.0 | 38.750N | 21.000E | | V | | | 49 | I | S | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 652 | 11 SEP 1960 | 01:45:18.0 | 38.750N | 21.000E | | | | | 49 | I | S | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 653 | 6 JAN 1966 | 02:01:51.6 | 39.300N | 21.300E | | | | | 49 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 654 | 6 FEB 1966 | 15:09:13.4 | 39.300N | 21.300E | | | 3.80 | | 49 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 655 | 10 FEB 1966 | 16:10:41.6 | 39.300N | 21.300E | | | 3.80 | | 49 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 656 | 15 MAR 1966 | 21:02:52.3 | 39.300N | 21.300E | | | | | 49 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 657 | 29 APR 1966 | 02:51:52.8 | 39.300N | 21.300E | | | | | 49 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 658 | 3 MAY 1966 | 12:56:14.5 | 39.300N | 21.300E | | | | | 49 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 659 | 23 MAY 1966 | 01:15:56.4 | 39.310N | 21.750E | | | | | 49 | I | S | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 660 | 18 JAN 1967 | 07:34:03.0 | 38.750N | 21.000E | | | | | 49 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>[illegible] STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SP | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 661 | 1 AUG 1968 | 21:29:21.3 | 38.460N | 21.600E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 662 | 19 FEB 1969 | 11:17:12.0 | 39.300N | 21.300E | | | | | | 49 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 663 | 18 AUG 1970 | 17:43:02.9 | 39.310N | 21.750E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 664 | 20 APR 1972 | 20:03:19.4 | 39.293N | 21.261E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 665 | 15 JUN 1972 | 07:09:51.2 | 38.584N | 21.920E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 666 | 16 JUN 1972 | 03:50:14.4 | 38.463N | 21.600E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 667 | 2 MAY 1973 | 09:03:23.0 | 38.981N | 22.082E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 668 | 2 MAY 1973 | 10:12:54.2 | 38.956N | 22.086E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |
| 669 | 31 AUG 1973 | 23:31:47.1 | 38.923N | 22.095E | | | | | 13 | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>21 STATION RECORDINGS USED IN SOLUTION |
| 670 | 15 SEP 1973 | 21:17:21.9 | 38.892N | 22.089E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 671 | 14 APR 1974 | 22:17:58.3 | 39.051N | 22.060E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 672 | 30 JUN 1975 | 14:21:53.1 | 38.489N | 21.721E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 673 | 2 JUL 1975 | 18:16:59.9 | 38.469N | 21.637E | | | | | | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 674 | 21 DEC 1975 | 16:07:51.1 | 38.470N | 21.667E | | | 5.20 | | 2 | 49 | | IS | ORIGINAL DATA SOURCE = ISC<br>242 STATION RECORDINGS USED IN SOLUTION |
| 675 | 4 OCT 1949 | 17:33:23.0 | 38.500N | 21.800E | | | | | | 50 | | IS | ORIGINAL DATA SOURCE = ISS |
| 676 | 5 OCT 1949 | 16:20:38.0 | 38.500N | 21.800E | | | | | | 50 | | IS | ORIGINAL DATA SOURCE = ISS |
| 677 | 18 MAY 1951 | 12:17:29.0 | 38.500N | 21.800E | | IV | | | | 50 | | IS | ORIGINAL DATA SOURCE = ISS |
| 678 | 4 MAR 1953 | 15:30:32.0 | 38.500N | 21.800E | | VII | | | | 50 | | IS | ORIGINAL DATA SOURCE = ISS |

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CAT.     DATE       TIME(GMT)      LAT       LONG    SL INTEN  MAG SM  H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR  HR-MIN-SEC                           (MM)         (KM)(KM)
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679    6 OCT 1954  12:01:41.0  38.500N  21.800E      III                 50   IS ORIGINAL DATA SOURCE =  BCIS

680   16 FEB 1958  16:30:10.0  38.500N  21.900E      VI     5.13         50   IS ORIGINAL DATA SOURCE =  BCIS
                                                                                 MAGNITUDE AUTHORITY =  ATH

681   14 AUG 1965  04:47:51.7  38.450N  21.600E             4.40     30  50   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   24 STATION RECORDINGS USED IN SOLUTION

682   10 MAR 1966  01:23:41.5  39.200N  21.100E                          50   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

683    9 SEP 1966  17:04:36.5  38.810N  20.970E                      95  50   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     7 STATION RECORDINGS USED IN SOLUTION

684   29 OCT 1966  17:51:01.8  38.840N  20.960E                      34  50   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   17 STATION RECORDINGS USED IN SOLUTION

685   11 JAN 1967  21:22:05.8  38.500N  21.800E                          50   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

686   10 JUN 1967  12:51:01.7  39.200N  21.100E             3.30         50   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

687    4 OCT 1968  17:19:48.0  39.200N  21.100E                          50   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH

688   18 DEC 1968  08:10:23.0  39.200N  21.100E                          50   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     3 STATION RECORDINGS USED IN SOLUTION

689    1 MAY 1969  02:10:23.0  39.200N  21.100E             3.30         50   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION

690   30 JAN 1970  19:17:24.0  39.300N  21.800E             3.40         50   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                     5 STATION RECORDINGS USED IN SOLUTION

691    1 JAN 1973  12:20:50.7  38.448N  21.538E                          50   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     6 STATION RECORDINGS USED IN SOLUTION

692   29 JUN 1975  17:36:57.0  38.474N  21.730E             4.10     39  50   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   72 STATION RECORDINGS USED IN SOLUTION

693   30 JUN 1975  18:40:32.0  38.455N  21.611E             4.30     41  50   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   84 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 694 | 3 JUL 1975 | 10:33:32.5 | 38.454N | 21.552E | | | 3.80 | | 42 | 50 | | IS | ORIGINAL DATA SOURCE = ISC<br>23 STATION RECORDINGS USED IN SOLUTION |
| 695 | 21 DEC 1975 | 23:25:24.6 | 38.449N | 21.581E | | | | | | 50 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 696 | 31 DEC 1975 | 13:46:06.0 | 38.465N | 21.680E | | | | | | 50 | | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 697 | 31 DEC 1975 | 22:39:12.0 | 38.493N | 21.783E | | | | | | 50 | | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 698 | 3 JAN 1955 | 01:07:03.0 | 39.000N | 22.100E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISS |
| 699 | 10 JAN 1964 | 03:34:24.0 | 38.700N | 21.000E | | | 4.60 | | 40 | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 700 | 28 OCT 1966 | 15:42:17.7 | 39.230N | 21.120E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 701 | 22 DEC 1966 | 17:54:22.0 | 39.100N | 21.000E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 702 | 1 APR 1969 | 21:05:10.0 | 39.000N | 22.100E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 703 | 3 MAY 1973 | 02:03:56.9 | 38.914N | 22.122E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 704 | 11 MAY 1973 | 23:53:26.8 | 38.835N | 22.109E | | | | | 5 | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 705 | 1 SEP 1973 | 01:05:39.5 | 38.917N | 22.112E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 706 | 27 DEC 1973 | 13:04:48.2 | 38.523N | 21.856E | | | | | 5 | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 707 | 7 DEC 1974 | 14:33:59.0 | 38.438N | 21.559E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 708 | 30 JUN 1975 | 17:03:14.5 | 38.452N | 21.637E | | | | | 3 | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 709 | 4 JUL 1975 | 02:17:51.5 | 38.458N | 21.687E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 710 | 30 DEC 1975 | 23:20:59.3 | 38.457N | 21.697E | | | | | | 51 | | IS | ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 711 | 11 SEP 1965 | 04:49:12.8 | 39.070N | 22.090E | | | 4.40 | | 42 | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>31 STATION RECORDINGS USED IN SOLUTION |
| 712 | 24 MAR 1968 | 09:53:11.2 | 38.440N | 21.660E | | | 4.30 | | | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 713 | 3 JUN 1971 | 00:46:41.2 | 39.200N | 21.068E | | | | | | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 714 | 30 JUL 1973 | 22:50:53.4 | 38.780N | 22.114E | | | | | | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 715 | 18 NOV 1973 | 02:27:57.9 | 39.046N | 20.955E | | | | | | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 716 | 23 MAR 1975 | 22:38:40.8 | 39.369N | 21.555E | | | | | | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 717 | 1 JUL 1975 | 04:11:39.9 | 38.436N | 21.602E | | | | | | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 718 | 30 DEC 1975 | 15:54:39.9 | 38.464N | 21.738E | | | | | | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>23 STATION RECORDINGS USED IN SOLUTION |
| 719 | 31 DEC 1975 | 10:10:16.5 | 38.432N | 21.526E | | | | | 21 | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 720 | 31 DEC 1975 | 14:53:41.5 | 38.453N | 21.703E | | | 4.50 | | 26 | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>80 STATION RECORDINGS USED IN SOLUTION |
| 721 | 31 DEC 1975 | 17:07:20.6 | 38.450N | 21.691E | | | | | 45 | 52 | IS | ORIGINAL DATA SOURCE = ISC<br>45 STATION RECORDINGS USED IN SOLUTION |
| 722 | 8 JAN 1955 | 07:53:01.0 | 39.200N | 22.000E | | VII | 5.20 | | | 53 | IS | ORIGINAL DATA SOURCE = ISS |
| 723 | 25 APR 1959 | 09:31:00.0 | 39.200N | 22.000E | | V | 5.13 | | | 53 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 724 | 21 OCT 1966 | 16:07:06.4 | 38.600N | 22.000E | | | | | | 53 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 725 | 5 JAN 1967 | 03:58:10.7 | 38.600N | 22.000E | | | | | | 53 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 726 | 3 MAY 1967 | 23:21:21.9 | 39.380N | 21.570E | | | | | 85 | 53 | IS | ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 727 | 8 AUG 1971 | 19:39:28.7 | 38.443N | 21.686E | | | 4.40 | | 36 | 53 | IS | ORIGINAL DATA SOURCE = ISC<br>50 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SP | H (KM) | DIS (KM) | QS | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 728 | 7 JAN 1972 | 23:11:08.9 | 39.336N | 21.783E | | | | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 729 | 27 APR 1972 | 22:11:56.1 | 38.877N | 20.921E | | | | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 730 | 18 SEP 1972 | 17:33:59.2 | 38.548N | 21.126E | | | | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 731 | 22 FEB 1974 | 15:26:49.8 | 39.113N | 20.980E | | | | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 732 | 21 NOV 1974 | 12:04:25.1 | 39.011N | 20.934E | | | | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 733 | 30 JUN 1975 | 15:27:28.1 | 38.438N | 21.671E | | | 4.30 | | 47 | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>45 STATION RECORDINGS USED IN SOLUTION |
| 734 | 1 JUL 1975 | 03:03:42.0 | 38.460N | 21.768E | | | | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 735 | 1 JUL 1975 | 08:24:22.9 | 38.513N | 21.879E | | | | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 736 | 2 JUL 1975 | 01:03:43.1 | 38.455N | 21.747E | | | 4.10 | | 17 | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>41 STATION RECORDINGS USED IN SOLUTION |
| 737 | 2 JUL 1975 | 04:48:31.3 | 38.471N | 21.793E | | | 4.10 | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>39 STATION RECORDINGS USED IN SOLUTION |
| 738 | 27 DEC 1975 | 12:08:49.3 | 38.462N | 21.786E | | | | | | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 739 | 31 DEC 1975 | 15:19:52.5 | 38.428N | 21.650E | | | | | 16 | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |
| 740 | 31 DEC 1975 | 17:36:53.1 | 38.422N | 21.516E | | | | | 39 | 53 | | IS ORIGINAL DATA SOURCE = ISC<br>37 STATION RECORDINGS USED IN SOLUTION |
| 741 | 24 JUL 1966 | 13:37:31.2 | 38.570N | 21.990E | | | | | | 54 | | IS ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 742 | 1 MAY 1967 | 08:28:23.0 | 39.390N | 21.500E | | | 4.40 | | 34 | 54 | | IS ORIGINAL DATA SOURCE = ISC<br>31 STATION RECORDINGS USED IN SOLUTION |
| 743 | 1 MAY 1967 | 14:38:02.0 | 39.360N | 21.310E | | | 4.50 | | 21 | 54 | | IS ORIGINAL DATA SOURCE = ISC<br>49 STATION RECORDINGS USED IN SOLUTION |
| 744 | 24 AUG 1970 | 21:11:34.8 | 39.170N | 22.050E | | | | | | 54 | | IS ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 745 | 3 APR 1972 | 13:40:20.6 | 39.127N | 22.083E | | | | | 1 | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 746 | 23 APR 1972 | 09:43:21.8 | 39.264N | 21.123E | | | | | | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 747 | 15 NOV 1972 | 12:57:51.7 | 38.418N | 21.622E | | | | | 4 | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 748 | 2 JUL 1973 | 21:24:35.7 | 38.423N | 21.442E | | | | | 8 | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 749 | 25 OCT 1974 | 03:29:49.8 | 38.812N | 20.922E | | | | | | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 750 | 7 DEC 1974 | 11:18:47.1 | 38.418N | 21.622E | | | | | | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 751 | 2 JUL 1975 | 18:22:14.6 | 38.434N | 21.713E | | | | | | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 752 | 2 JUL 1975 | 18:58:01.2 | 38.459N | 21.782E | | | | | | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 753 | 27 SEP 1975 | 14:10:46.0 | 39.100N | 22.100E | | | | | | 54 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 754 | 24 DEC 1975 | 12:36:25.3 | 38.470N | 21.831E | | | | | | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 755 | 31 DEC 1975 | 13:02:08.1 | 38.410N | 21.545E | | | | | 37 | 54 | | IS | ORIGINAL DATA SOURCE = ISC<br>37 STATION RECORDINGS USED IN SOLUTION |
| 756 | 11 APR 1952 | 07:40:22.0 | 38.900N | 20.900E | | IV | | | | 55 | | IS | ORIGINAL DATA SOURCE = BCIS |
| 757 | 11 APR 1952 | 07:40:24.0 | 38.900N | 20.900E | | IV | | | | 55 | | IS | ORIGINAL DATA SOURCE = ISS |
| 758 | 6 SEP 1965 | 23:06:48.5 | 39.300N | 21.900E | | | 3.60 | | | 55 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 759 | 4 AUG 1968 | 00:53:03.1 | 39.000N | 22.150E | | | 4.00 | | 89 | 55 | | IS | ORIGINAL DATA SOURCE = ISC<br>20 STATION RECORDINGS USED IN SOLUTION |
| 760 | 28 NOV 1968 | 13:14:02.0 | 38.910N | 20.900E | | | | | | 55 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 761 | 4 FEB 1971 | 00:39:16.1 | 38.482N | 21.870E | | | | | 6 | 55 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 762 | 5 JUL 1973 | 13:06:49.8 | 39.325N | 21.853E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 763 | 22 OCT 1974 | 10:26:09.7 | 38.639N | 20.998E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 764 | 24 OCT 1974 | 18:23:17.3 | 38.857N | 20.900E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 765 | 25 NOV 1974 | 02:53:47.6 | 38.472N | 21.844E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 766 | 21 DEC 1974 | 21:28:35.7 | 38.809N | 22.150E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |
| 767 | 29 JUN 1975 | 20:50:23.2 | 38.432N | 21.748E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 768 | 30 JUN 1975 | 03:37:14.8 | 38.451N | 21.788E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 769 | 30 JUN 1975 | 13:39:47.0 | 38.428N | 21.705E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 770 | 2 JUL 1975 | 18:49:49.3 | 38.425N | 21.714E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 771 | 5 JUL 1975 | 04:32:44.0 | 38.434N | 21.730E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 772 | 23 DEC 1975 | 15:20:41.1 | 38.464N | 21.837E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 773 | 24 DEC 1975 | 11:12:03.0 | 38.500N | 21.900E | | | | | | 55 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 774 | 24 DEC 1975 | 22:34:12.0 | 38.500N | 21.900E | | | | | | 55 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 775 | 26 DEC 1975 | 18:56:59.0 | 38.415N | 21.677E | | | | | | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 776 | 31 DEC 1975 | 06:34:04.4 | 38.423N | 21.700E | | | 4.20 | | 28 | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>53 STATION RECORDINGS USED IN SOLUTION |
| 777 | 31 DEC 1975 | 17:03:57.4 | 38.412N | 21.657E | | | | | 49 | 55 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | CIS (KM) | Q | S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 778 | 15 AUG 1932 | 04:34:40.0 | 39.250N | 22.000E | | - | 5.50 | | 100 | 56 | I | S | QUALITY = -BBB<br>ORIGINAL DATA SOURCE = GUTE<br>MAGNITUDE AUTHORITY = PAS |
| 779 | 6 FEB 1966 | 02:52:11.0 | 39.400N | 21.500E | | | | | | 56 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 780 | 21 FEB 1966 | 09:29:59.4 | 39.250N | 22.000E | | | 3.50 | | | 56 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 781 | 23 JUN 1966 | 21:02:54.3 | 39.160N | 22.090E | | | | | | 56 | I | S | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 782 | 21 JUL 1966 | 11:30:50.2 | 39.400N | 21.600E | | | | | | 56 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 783 | 7 AUG 1966 | 08:06:57.0 | 39.250N | 22.000E | | | | | | 56 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 784 | 17 AUG 1966 | 10:31:28.3 | 39.250N | 22.000E | | | | | | 56 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 785 | 27 AUG 1966 | 08:09:22.2 | 39.250N | 22.000E | | | | | | 56 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 786 | 12 OCT 1968 | 22:40:24.0 | 38.400N | 21.600E | | | | | | 56 | I | S | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 787 | 24 SEP 1969 | 03:34:33.0 | 38.400N | 21.600E | | | | | | 56 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 788 | 10 NOV 1969 | 19:14:06.0 | 38.400N | 21.600E | | | | | 143 | 56 | I | S | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 789 | 18 JUL 1970 | 22:48:32.4 | 38.780N | 20.900E | | | | | | 56 | I | S | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 790 | 28 AUG 1970 | 19:41:15.1 | 38.410N | 21.700E | | | | | | 56 | I | S | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 791 | 10 OCT 1972 | 16:20:51.2 | 38.520N | 21.954E | | | | | | 56 | I | S | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 792 | 13 DEC 1972 | 22:16:59.7 | 39.095N | 22.126E | | | | | | 56 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 793 | 29 JUN 1975 | 16:56:29.2 | 38.414N | 21.715E | | | | | 13 | 56 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 794 | 30 JUN 1975 | 15:39:28.0 | 38.400N | 21.600E | | | 3.10 | | | 56 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 795 | 1 JUL 1975 | 03:50:43.2 | 38.424N | 21.728E | | | | | 11 | 56 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 796 | 2 JUL 1975 | 18:34:16.3 | 38.410N | 21.680E | | | | | 6 | 56 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 797 | 3 JUL 1975 | 08:59:47.4 | 38.431N | 21.761E | | | | | | 56 | IS | ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |
| 798 | 24 SEP 1965 | 14:56:35.0 | 38.400N | 21.700E | | | 3.40 | | | 57 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 799 | 26 OCT 1965 | 00:51:04.0 | 38.600N | 21.000E | | | | | | 57 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 800 | 5 FEB 1966 | 19:00:22.2 | 39.400N | 21.700E | | | | | | 57 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 801 | 11 FEB 1966 | 00:57:54.0 | 39.200N | 21.000E | | | | | | 57 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 802 | 13 FEB 1966 | 17:20:12.6 | 39.400N | 21.700E | | | | | | 57 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 803 | 18 APR 1967 | 19:24:59.6 | 38.400N | 21.700E | | | 3.10 | | | 57 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 804 | 18 APR 1967 | 19:45:20.2 | 38.400N | 21.700E | | | 3.20 | | | 57 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 805 | 29 AUG 1967 | 21:59:03.0 | 38.450N | 21.850E | | | | | | 57 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 806 | 7 SEP 1967 | 17:23:22.0 | 39.400N | 21.400E | | | 3.80 | | | 57 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |

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CAT.     DATE       TIME(GMT)       LAT       LONG     SL INTEN  MAG SM  H  CIS Q S          L O C A T I O N     A N D     C O M M E N T S
NO.  DAY-MO-YEAR   HR-MIN-SEC                             (MM)          (KM)(KM)
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                                                                                            3 STATION RECORDINGS USED IN SOLUTION
807    9 OCT 1969  15:30:23.0  38.400N  21.700E                              57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                            7 STATION RECORDINGS USED IN SOLUTION
808   20 FEB 1970  12:56:40.7  38.470N  21.890E                              57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                            5 STATION RECORDINGS USED IN SOLUTION
809    1 JUN 1970  01:15:48.6  38.940N  20.870E             4.00        47   57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           39 STATION RECORDINGS USED IN SOLUTION
810    5 AUG 1970  20:41:16.5  39.290N  21.100E                         36   57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           16 STATION RECORDINGS USED IN SOLUTION
811   15 JUN 1972  02:51:04.0  38.389N  21.560E                              57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                            4 STATION RECORDINGS USED IN SOLUTION
812    7 DEC 1974  18:29:03.6  38.421N  21.757E                              57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           17 STATION RECORDINGS USED IN SOLUTION
813   30 JUN 1975  13:21:31.5  38.428N  21.778E                              57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           10 STATION RECORDINGS USED IN SOLUTION
814    2 JUL 1975  01:08:46.3  38.476N  21.900E                              57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           11 STATION RECORDINGS USED IN SOLUTION
815    4 JUL 1975  00:24:49.2  38.399N  21.671E             4.20        33   57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           47 STATION RECORDINGS USED IN SOLUTION
816   21 DEC 1975  19:08:27.0  38.400N  21.700E                              57      IS DATA OBTAINED VIA ISC
                                                                                         ORIGINAL DATA SOURCE =  ATH
                                                                                            0 STATION RECORDINGS USED IN SOLUTION
817   21 DEC 1975  19:31:46.6  38.392N  21.617E             4.20        30   57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           18 STATION RECORDINGS USED IN SOLUTION
818   31 DEC 1975  08:46:21.0  38.425N  21.771E                              57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           11 STATION RECORDINGS USED IN SOLUTION
819   31 DEC 1975  11:31:27.8  38.397N  21.645E                         34   57      IS ORIGINAL DATA SOURCE =  ISC
                                                                                           37 STATION RECORDINGS USED IN SOLUTION
820   24 OCT 1955  20:10:34.0  38.500N  21.100E     V                        58      IS ORIGINAL DATA SOURCE =  BCIS
821   29 MAY 1966  18:38:29.3  39.300N  21.100E                              58      IS DATA OBTAINED VIA ISC
                                                                                         ORIGINAL DATA SOURCE =  ATH
                                                                                            4 STATION RECORDINGS USED IN SOLUTION
822    8 MAR 1969  06:11:56.0  38.900N  22.200E                              58      IS ORIGINAL DATA SOURCE =  ISC
                                                                                            6 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 823 | 9 DEC 1972 | 04:28:19.9 | 38.452N | 21.874E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 824 | 20 JAN 1973 | 13:44:47.1 | 38.385N | 21.646E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 825 | 24 JUN 1973 | 22:03:30.6 | 38.983N | 22.187E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 826 | 29 APR 1975 | 22:52:42.5 | 38.430N | 21.832E | | | | | 16 | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 827 | 24 JUN 1975 | 03:44:59.1 | 38.439N | 21.833E | | | 3.80 | | 60 | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>31 STATION RECORDINGS USED IN SOLUTION |
| 828 | 30 JUN 1975 | 15:38:26.8 | 38.396N | 21.698E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 829 | 3 JUL 1975 | 08:41:55.5 | 38.415N | 21.789E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 830 | 14 JUL 1975 | 08:10:50.8 | 38.421N | 21.787E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 831 | 29 SEP 1975 | 20:06:21.1 | 39.064N | 22.160E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 832 | 31 DEC 1975 | 17:18:23.7 | 38.409N | 21.772E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 833 | 31 DEC 1975 | 20:03:50.1 | 38.406N | 21.730E | | | | | | 58 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 834 | 12 AUG 1953 | 09:23:50.6 | 38.700N | 20.900E | | | 7.20 | | | 59 | IS | DATA OBTAINED VIA BCIS<br>REPORTED FELT INFORMATION<br>ORIGINAL DATA SOURCE = ROM<br>MAGNITUDE AUTHORITY = ROM |
| 835 | 12 AUG 1953 | 09:23:52.0 | 38.700N | 20.900E | | | | | | 59 | IS | DATA OBTAINED VIA ISS<br>ORIGINAL DATA SOURCE = ROM |
| 836 | 20 JUN 1965 | 00:40:47.4 | 38.800N | 22.200E | | | | | 10 | 59 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 837 | 31 DEC 1965 | 22:43:19.8 | 39.100N | 20.900E | | | 4.10 | | | 59 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>6 STATION RECORDINGS USED IN SOLUTION |
| 838 | 5 MAY 1966 | 00:03:02.1 | 39.400N | 21.300E | | | | | | 59 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SP | H (KM) | CIS (KM) | Q | S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 839 | 24 JUL 1966 | 02:11:10.6 | 38.810N | 22.200E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 840 | 9 AUG 1966 | 21:11:18.8 | 39.400N | 21.300E | | | | | | 59 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 841 | 17 AUG 1966 | 19:02:01.0 | 39.400N | 21.300E | | | 3.80 | | | 59 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 842 | 17 JUL 1967 | 18:57:04.0 | 39.400N | 21.300E | | | 3.60 | | | 59 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 843 | 1 AUG 1968 | 08:07:37.0 | 38.700N | 20.900E | | | 3.60 | | | 59 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 844 | 1 APR 1969 | 19:23:50.0 | 38.800N | 22.200E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 845 | 24 MAY 1970 | 04:14:14.0 | 38.800N | 22.200E | | | 3.20 | | | 59 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 846 | 9 MAY 1971 | 17:19:37.8 | 38.778N | 22.193E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 847 | 20 NOV 1972 | 03:30:27.2 | 39.419N | 21.679E | | | 4.80 | | 26 | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>99 STATION RECORDINGS USED IN SOLUTION |
| 848 | 23 JAN 1973 | 15:17:41.4 | 39.411N | 21.326E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 849 | 20 MAR 1973 | 06:02:38.6 | 39.234N | 22.062E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 850 | 8 APR 1974 | 17:31:05.9 | 39.428N | 21.537E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 851 | 16 JUN 1974 | 21:12:53.4 | 39.133N | 20.922E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 852 | 16 NOV 1974 | 14:20:17.0 | 38.676N | 20.914E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 853 | 22 JAN 1975 | 22:13:56.0 | 39.036N | 20.870E | | | | | | 59 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE       TIME(GMT)       LAT      LONG    SL INTEN  MAG SM  H  DIS Q S        L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                            (MM)          (KM)(KM)
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854  23 DEC 1975  18:55:03.1  38.499N  21.980E                             59  IS ORIGINAL DATA SOURCE =  ISC
                                                                                     5 STATION RECORDINGS USED IN SOLUTION

855  31 DEC 1975  16:14:28.9  38.367N  21.502E                         61  59  IS ORIGINAL DATA SOURCE =  ISC
                                                                                    12 STATION RECORDINGS USED IN SOLUTION

856   9 NOV 1957  23:55:50.0  38.500N  22.000E                             60  IS DATA OBTAINED VIA USE
                                                                                  REPORTED FELT INFORMATION
                                                                                  ORIGINAL DATA SOURCE =  CGS

857   7 MAY 1960  11:33:28.0  39.250N  21.000E                             60  IS QUALITY =    APRX
                                                                                  ORIGINAL DATA SOURCE =  BCIS

858  16 JUL 1962  07:03:40.0  38.500N  22.000E    V      4.50              60  IS DATA OBTAINED VIA BCIS
                                                                                  ORIGINAL DATA SOURCE =  MOS
                                                                                  MAGNITUDE AUTHORITY =   MOS

859  16 JUL 1962  07:03:41.0  38.500N  22.000E    V      4.75              60  IS ORIGINAL DATA SOURCE =  BCIS
                                                                                  MAGNITUDE AUTHORITY =   ATH

860  24 SEP 1962  23:30:10.0  39.300N  22.000E    VI                       60  IS ORIGINAL DATA SOURCE =  BCIS

861  17 SEP 1964  21:07:28.0  38.500N  22.000E                             60  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     3 STATION RECORDINGS USED IN SOLUTION

862  17 SEP 1964  22:46:31.0  38.500N  22.000E                             60  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

863  20 SEP 1964  01:55:21.0  38.500N  22.000E                             60  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

864   1 NOV 1964  19:14:04.0  38.500N  22.000E                             60  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

865  16 NOV 1964  12:38:44.0  38.500N  22.000E                             60  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     2 STATION RECORDINGS USED IN SOLUTION

866  26 JAN 1965  06:00:26.0  39.250N  21.000E                             60  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     0 STATION RECORDINGS USED IN SOLUTION

867  15 FEB 1966  23:33:42.3  39.250N  21.000E                             60  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                     4 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | L O C A T I O N   A N D   C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 868 | 14 MAY 1966 | 13:36:07.5 | 39.250N | 21.000E | | | | | | 60 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 869 | 22 MAY 1966 | 07:42:17.0 | 39.250N | 21.000E | | | | | | 60 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>12 STATION RECORDINGS USED IN SOLUTION |
| 870 | 25 DEC 1966 | 08:17:42.5 | 39.250N | 21.000E | | | | | | 60 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 871 | 21 APR 1968 | 14:00:08.0 | 39.250N | 21.000E | | | | | | 60 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 872 | 26 AUG 1968 | 21:43:38.0 | 38.400N | 21.800E | | | | | | 60 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 873 | 24 JAN 1969 | 09:28:30.0 | 38.500N | 22.000E | | | 3.10 | | | 60 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 874 | 13 APR 1969 | 09:23:58.0 | 38.500N | 22.000E | | | | | | 60 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 875 | 9 JUL 1970 | 08:29:51.5 | 38.890N | 20.840E | | | | | | 60 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 876 | 17 AUG 1970 | 11:04:22.0 | 38.400N | 21.800E | | | 3.10 | | | 60 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 877 | 7 JUN 1972 | 05:40:33.1 | 38.370N | 21.633E | | | | | | 60 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 878 | 8 AUG 1972 | 07:45:49.1 | 38.882N | 20.835E | | | | | | 60 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 879 | 22 FEB 1973 | 18:26:06.9 | 38.598N | 22.100E | | | | | | 60 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 880 | 25 OCT 1973 | 01:35:22.3 | 39.080N | 22.185E | | | | | | 60 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 881 | 22 OCT 1974 | 21:36:27.4 | 38.889N | 22.223E | | | | | 3 | 60 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
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| 882 | 10 FEB 1968 | 17:24:49.0 | 39.220N | 22.100E | | | | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 883 | 23 SEP 1968 | 05:09:23.9 | 39.200N | 20.940E | | | | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 884 | 4 APR 1972 | 21:12:29.6 | 39.333N | 21.102E | | | | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 885 | 16 APR 1973 | 14:28:33.3 | 38.817N | 20.836E | | | 4.00 | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>26 STATION RECORDINGS USED IN SOLUTION |
| 886 | 6 DEC 1974 | 13:32:28.5 | 38.387N | 21.795E | | | | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 887 | 22 NOV 1975 | 18:33:23.9 | 38.405N | 21.838E | | | | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 888 | 22 DEC 1975 | 15:05:02.7 | 39.081N | 22.200E | | | | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 889 | 31 DEC 1975 | 10:07:32.1 | 38.357N | 21.439E | | | | | 40 | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>20 STATION RECORDINGS USED IN SOLUTION |
| 890 | 31 DEC 1975 | 12:19:05.2 | 38.352N | 21.517E | | | | | 79 | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |
| 891 | 31 DEC 1975 | 15:14:36.2 | 38.381N | 21.759E | | | 4.30 | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>54 STATION RECORDINGS USED IN SOLUTION |
| 892 | 31 DEC 1975 | 22:47:06.7 | 38.395N | 21.811E | | | | | | 61 | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 893 | 22 MAR 1966 | 17:12:43.8 | 39.400N | 21.200E | | | | | | 62 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 894 | 13 AUG 1969 | 04:06:03.0 | 38.370N | 21.750E | | | 4.50 | | 24 | 62 | IS | ORIGINAL DATA SOURCE = ISC<br>66 STATION RECORDINGS USED IN SOLUTION |
| 895 | 15 AUG 1969 | 04:14:12.5 | 38.350N | 21.640E | | | | | | 62 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 896 | 5 JAN 1970 | 16:58:22.7 | 38.360N | 21.700E | | | | | | 62 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 897 | 5 JUN 1971 | 19:55:51.6 | 38.401N | 21.862E | | | 4.40 | | 2 | 62 | IS | ORIGINAL DATA SOURCE = ISC<br>29 STATION RECORDINGS USED IN SOLUTION |
| 898 | 9 JAN 1972 | 09:45:03.7 | 38.914N | 22.239E | | | | | | 62 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE      TIME(GMT)     LAT     LONG    SL INTEN MAG SM  H  DIS Q S     L O C A T I O N   A N D   C O M M E N T S
NO.   DAY-MO-YEAR  HR-MIN-SEC                          (MM)         (KM)(KM)
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899   12 MAY 1972  08:53:06.8  39.222N  20.946E                       62   IS ORIGINAL DATA SOURCE =  ISC
                                                                              5 STATION RECORDINGS USED IN SOLUTION

900    2 MAY 1973  07:49:02.6  39.063N  22.211E                   33  62   IS ORIGINAL DATA SOURCE =  ISC
                                                                             16 STATION RECORDINGS USED IN SOLUTION

901   23 AUG 1974  07:42:37.5  38.408N  21.856E                       62   IS ORIGINAL DATA SOURCE =  ISC
                                                                              6 STATION RECORDINGS USED IN SOLUTION

902    2 JUL 1975  03:30:01.0  38.350N  21.658E                   13  62   IS ORIGINAL DATA SOURCE =  ISC
                                                                              8 STATION RECORDINGS USED IN SOLUTION

903    9 JUL 1975  03:47:56.4  38.348N  21.670E                       62   IS ORIGINAL DATA SOURCE =  ISC
                                                                              8 STATION RECORDINGS USED IN SOLUTION

904   25 JUL 1975  19:17:12.3  38.406N  21.867E           4.80    38  62   IS ORIGINAL DATA SOURCE =  ISC
                                                                            176 STATION RECORDINGS USED IN SOLUTION

905   24 DEC 1975  04:31:48.0  38.434N  21.926E                       62   IS ORIGINAL DATA SOURCE =  ISC
                                                                              7 STATION RECORDINGS USED IN SOLUTION

906   27 DEC 1975  09:51:15.8  38.356N  21.700E                       62   IS ORIGINAL DATA SOURCE =  ISC
                                                                              9 STATION RECORDINGS USED IN SOLUTION

907   31 DEC 1975  11:26:21.2  38.362N  21.701E                       62   IS ORIGINAL DATA SOURCE =  ISC
                                                                             15 STATION RECORDINGS USED IN SOLUTION

908   31 DEC 1975  15:03:07.4  38.350N  21.660E                       62   IS ORIGINAL DATA SOURCE =  ISC
                                                                             14 STATION RECORDINGS USED IN SOLUTION

909   31 DEC 1975  15:56:20.9  38.388N  21.801E                       62   IS ORIGINAL DATA SOURCE =  ISC
                                                                             12 STATION RECORDINGS USED IN SOLUTION

910   13 MAR 1957  11:20:55.0  39.000N  22.250E     IV                63   IS ORIGINAL DATA SOURCE =  BCIS
911    3 OCT 1966  13:15:29.4  38.900N  20.800E                       63   IS DATA OBTAINED VIA ISC
                                                                            ORIGINAL DATA SOURCE =  ATH
                                                                              3 STATION RECORDINGS USED IN SOLUTION

912   18 JAN 1968  06:41:17.0  38.900N  20.800E           5.80        63  .IS DATA OBTAINED VIA ISC
                                                                            ORIGINAL DATA SOURCE =  ATH
                                                                              3 STATION RECORDINGS USED IN SOLUTION

913   31 JAN 1969  13:41:42.0  38.900N  20.800E                       63   IS ORIGINAL DATA SOURCE =  ISC
                                                                              6 STATION RECORDINGS USED IN SOLUTION

914   25 JUL 1974  07:50:36.7  38.337N  21.654E                       63   IS ORIGINAL DATA SOURCE =  ISC
                                                                              5 STATION RECORDINGS USED IN SOLUTION

915   11 JAN 1975  16:41:56.7  38.335N  21.523E                       63   IS ORIGINAL DATA SOURCE =  ISC
                                                                              8 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | -H (KM) | DIS (KM) | Q S | L O C A T I O N A N D C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 916 | 10 MAR 1975 | 08:20:41.3 | 38.919N | 20.804E | | | | | | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 917 | 8 MAY 1975 | 20:28:14.2 | 38.672N | 20.866E | | | | | | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 918 | 14 MAY 1975 | 03:05:26.1 | 39.113N | 20.858E | | | | | | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 919 | 6 JUN 1975 | 18:53:29.7 | 38.943N | 22.251E | | | 4.00 | | 41 | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>40 STATION RECORDINGS USED IN SOLUTION |
| 920 | 2 JUL 1975 | 04:25:31.8 | 38.352N | 21.700E | | | | | | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 921 | 2 JUL 1975 | 05:09:33.7 | 38.333N | 21.575E | | | | | 44 | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 922 | 13 SEP 1975 | 21:16:56.3 | 39.287N | 21.004E | | | | | | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 923 | 3 OCT 1975 | 10:33:14.0 | 39.000N | 22.250E | | | | | | 63 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 924 | 31 DEC 1975 | 12:07:53.5 | 38.364N | 21.767E | | | | | | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 925 | 31 DEC 1975 | 20:30:30.8 | 38.355N | 21.719E | | | | | | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 926 | 31 DEC 1975 | 20:36:25.6 | 38.342N | 21.653E | | | | | | 63 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 927 | 9 AUG 1953 | 07:41:05.0 | 38.500N | 21.000E | | II | 6.75 | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = FRSH<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = PAS |
| 928 | 11 AUG 1953 | 03:32:24.0 | 38.500N | 21.000E | | | 6.75 | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = FRSH<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = PAS |
| 929 | 11 AUG 1953 | 12:43:24.0 | 38.500N | 21.000E | | | 5.63 | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = FRSH<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = PRA |
| 930 | 11 AUG 1953 | 13:11:06.0 | 38.500N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = FRSH |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
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| | | | | | | | | | | | | ORIGINAL DATA SOURCE = PDE |
| 931 | 12 AUG 1953 | 06:08:03.0 | 38.500N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = FRSH<br>ORIGINAL DATA SOURCE = PDE |
| 932 | 12 AUG 1953 | 09:23:55.0 | 38.500N | 21.000E | | | 7.25 | | | 64 | IS | DATA OBTAINED VIA BCIS<br>REPORTED FELT INFORMATION<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = PAS |
| 933 | 12 AUG 1953 | 11:33:46.0 | 38.500N | 21.000E | | | 5.63 | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = PRA |
| 934 | 12 AUG 1953 | 13:39:23.0 | 38.500N | 21.000E | | | 5.50 | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = PRA |
| 935 | 12 AUG 1953 | 14:08:38.0 | 38.500N | 21.000E | | | 6.00 | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = PAS |
| 936 | 12 AUG 1953 | 16:08:32.0 | 38.500N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE |
| 937 | 13 AUG 1953 | 03:22:06.0 | 38.500N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE |
| 938 | 13 AUG 1953 | 10:16:50.0 | 38.500N | 21.000E | | | 5.00 | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = PRA |
| 939 | 17 AUG 1953 | 02:12:22.0 | 38.500N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE |
| 940 | 18 AUG 1953 | 22:43:47.0 | 38.500N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE |
| 941 | 20 AUG 1953 | 19:27:18.0 | 38.500N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SP | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
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| 942 | 28 AUG 1953 | 20:38:56.0 | 38.500N | 21.000E | | | | | | 64 | | | IS DATA OBTAINED VIA BCIS<br>QUALITY = REPT<br>ORIGINAL DATA SOURCE = PDE |
| 943 | 6 OCT 1953 | 17:03:56.0 | 38.500N | 21.000E | | | | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 944 | 10 OCT 1953 | 21:29:14.0 | 38.500N | 21.000E | | VI | 5.37 | | | 64 | | | IS DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = PDE<br>MAGNITUDE AUTHORITY = HRB |
| 945 | 11 OCT 1953 | 00:14:15.0 | 38.500N | 21.000E | | IV | | | | 64 | | | IS QUALITY = REPT<br>ORIGINAL DATA SOURCE = BCIS |
| 946 | 16 OCT 1953 | 21:44:49.0 | 38.500N | 21.000E | | VI | 4.87 | | | 64 | | | IS DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = ROM<br>MAGNITUDE AUTHORITY = PRA |
| 947 | 21 DEC 1953 | 04:47:47.0 | 38.500N | 21.000E | | V | | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 948 | 28 DEC 1953 | 02:38:43.0 | 38.500N | 21.000E | | VI | 5.50 | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 949 | 25 MAR 1955 | 12:21:37.0 | 38.500N | 21.000E | | IV | | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 950 | 25 DEC 1956 | 01:01:36.0 | 38.500N | 21.000E | | IV | | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 951 | 22 FEB 1960 | 21:04:16.0 | 39.000N | 20.800E | | VI | 5.25 | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 952 | 23 FEB 1960 | 00:31:00.0 | 39.000N | 20.800E | | VI | 5.13 | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 953 | 23 FEB 1960 | 07:34:33.0 | 39.000N | 20.800E | | VIII | 5.50 | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 954 | 23 FEB 1960 | 07:47:49.0 | 39.000N | 20.800E | | VI | 5.13 | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 955 | 11 NOV 1960 | 05:31:28.0 | 38.500N | 21.000E | | VII | 5.50 | | | 64 | | | IS DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = ATH |
| 956 | 2 NOV 1961 | 04:57:21.0 | 38.500N | 21.000E | | V | | | | 64 | | | IS QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 957 | 6 MAY 1962 | 21:40:30.0 | 38.500N | 21.000E | | V | | | | 64 | | | IS QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 958 | 6 MAY 1962 | 22:27:55.0 | 38.500N | 21.000E | | IV | | | | 64 | | | IS ORIGINAL DATA SOURCE = BCIS |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
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| 959 | 6 MAY 1962 | 23:36:30.0 | 38.500N | 21.000E | | V | | | | 64 | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 960 | 17 JUL 1962 | 03:01:12.0 | 38.500N | 21.000E | | | | | | 64 | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 961 | 17 DEC 1965 | 04:47:58.4 | 38.500N | 21.000F | | | | | | 64 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 962 | 16 JAN 1966 | 20:03:33.9 | 39.300N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 963 | 21 FEB 1966 | 13:40:12.6 | 39.400N | 21.900E | | | | | | 64 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 964 | 8 MAY 1966 | 06:22:57.0 | 39.000N | 20.800E | | | | | | 64 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 965 | 5 SEP 1966 | 22:34:13.3 | 38.400N | 21.900E | | | 4.30 | | 15 | 64 | IS | ORIGINAL DATA SOURCE = ISC<br>32 STATION RECORDINGS USED IN SOLUTION |
| 966 | 18 OCT 1966 | 22:16:49.2 | 39.300N | 21.000E | | | | | | 64 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 967 | 2 MAY 1967 | 08:11:55.9 | 39.450N | 21.290E | | | 4.50 | | 39 | 64 | IS | ORIGINAL DATA SOURCE = ISC<br>40 STATION RECORDINGS USED IN SOLUTION |
| 968 | 2 MAY 1967 | 09:56:20.4 | 39.390N | 21.140E | | | | | | 64 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 969 | 29 SEP 1968 | 00:38:52.0 | 39.200N | 20.900E | | | 3.40 | | | 64 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 970 | 21 MAR 1969 | 06:59:17.0 | 38.500N | 21.000E | | | 3.30 | | | 64 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 971 | 20 JUN 1969 | 21:50:38.0 | 39.400N | 21.900E | | | | | | 64 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 972 | 16 JUL 1970 | 12:52:31.0 | 39.300N | 21.000E | | | | | | 64 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 973 | 11 SEP 1970 | 09:49:58.0 | 38.400N | 21.900E | | | 3.30 | | | 64 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 974 | 14 OCT 1971 | 11:22:37.9 | 38.856N | 20.796E | | | | | | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 975 | 15 MAR 1972 | 19:17:38.1 | 39.225N | 20.926E | | | | | | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 976 | 1 MAY 1972 | 04:12:20.0 | 39.300N | 21.000E | | | 3.60 | | | 64 | | | IS DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 977 | 4 SEP 1973 | 07:37:51.1 | 38.757N | 22.248E | | | | | | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 978 | 2 FEB 1975 | 12:26:42.7 | 38.369N | 21.817E | | | | | | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 979 | 4 APR 1975 | 02:54:21.6 | 38.369N | 21.815E | | | | | 43 | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>15 STATION RECORDINGS USED IN SOLUTION |
| 980 | 30 JUN 1975 | 15:15:30.6 | 38.368N | 21.803E | | | | | | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 981 | 3 JUL 1975 | 21:12:25.5 | 38.371N | 21.821E | | | 3.80 | | | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>26 STATION RECORDINGS USED IN SOLUTION |
| 982 | 10 JUL 1975 | 05:19:05.9 | 38.326N | 21.509E | | | | | 19 | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 983 | 13 SEP 1975 | 14:30:37.6 | 38.465N | 22.016E | | | 4.80 | | 40 | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>150 STATION RECORDINGS USED IN SOLUTION |
| 984 | 21 DEC 1975 | 21:05:15.0 | 38.381N | 21.854E | | | 4.30 | | | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>41 STATION RECORDINGS USED IN SOLUTION |
| 985 | 24 DEC 1975 | 15:55:24.5 | 38.335N | 21.691E | | | | | 7 | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 986 | 31 DEC 1975 | 10:58:20.2 | 38.331N | 21.630E | | | | | 29 | 64 | | | IS ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 987 | 15 MAY 1958 | 14:46:11.0 | 38.750N | 22.250E | | V | 4.38 | | | 65 | | | IS ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 988 | 17 MAY 1958 | 20:58:02.0 | 38.750N | 22.250E | | V | | | | 65 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 989 | 2 JUN 1960 | 04:25:10.0 | 38.750N | 22.250E | | V | | | | 65 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 990 | 11 NOV 1960 | 05:31:26.0 | 38.770N | 20.800E | | | | | | 65 | | | IS ORIGINAL DATA SOURCE = ISS |
| 991 | 3 SEP 1967 | 14:39:23.8 | 38.410N | 21.930E | | | 4.30 | | | 65 | | | IS ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE       TIME(GMT)      LAT       LONG     SL INTEN  MAG SM  H  DIS Q S        L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR  HR-MIN-SEC                              (MM)          (KM)(KM)
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992   24 JUL 1968  20:56:21.1  38.400N  21.910E              4.40    36  65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   41 STATION RECORDINGS USED IN SOLUTION

993    1 OCT 1969  23:45:20.1  38.620N  22.190E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    5 STATION RECORDINGS USED IN SOLUTION

994   20 DEC 1969  14:02:10.0  38.750N  22.250E              3.10        65   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                    4 STATION RECORDINGS USED IN SOLUTION

995   30 MAR 1971  19:40:13.3  38.983N  20.786E              4.70    46  65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   72 STATION RECORDINGS USED IN SOLUTION

996   12 JUL 1971  11:51:21.0  39.196N  20.880E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    6 STATION RECORDINGS USED IN SOLUTION

997   12 NOV 1972  03:51:01.7  38.401N  21.916E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    6 STATION RECORDINGS USED IN SOLUTION

998   17 JUL 1973  05:02:44.8  39.249N  20.928E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    5 STATION RECORDINGS USED IN SOLUTION

999   20 SEP 1974  00:01:05.6  38.349N  21.281E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    7 STATION RECORDINGS USED IN SOLUTION

1000  17 OCT 1974  23:44:37.0  39.385N  21.119E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    7 STATION RECORDINGS USED IN SOLUTION

1001  23 JUN 1975  10:41:07.0  38.324N  21.669E              4.20     3  65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   39 STATION RECORDINGS USED IN SOLUTION

1002  30 JUN 1975  15:33:32.2  38.328N  21.680E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   16 STATION RECORDINGS USED IN SOLUTION

1003   9 SEP 1975  23:56:18.9  38.342N  21.764E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   10 STATION RECORDINGS USED IN SOLUTION

1004  14 DEC 1975  03:28:22.8  38.328N  21.701E                          65   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    8 STATION RECORDINGS USED IN SOLUTION

1005   8 JUN 1966  08:39:00.0  39.300N  22.100E              3.60        66   IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                    2 STATION RECORDINGS USED IN SOLUTION

1006   5 MAY 1967  14:50:03.3  39.420N  21.150E              4.30    45  66   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   31 STATION RECORDINGS USED IN SOLUTION

1007  22 JUN 1967  10:58:34.2  39.280N  20.950E                          66   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   19 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | FIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1008 | 31 OCT 1968 | 15:28:49.4 | 38.310N | 21.500E | | . | | | | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1009 | 19 SEP 1969 | 22:23:45.7 | 38.320N | 21.690E | | | | | | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1010 | 7 FEB 1971 | 16:56:04.4 | 38.319N | 21.682E | | | | | | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1011 | 14 JUN 1973 | 20:22:08.6 | 38.381N | 21.896E | | | | | | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 1012 | 8 JUN 1974 | 18:57:19.4 | 38.958N | 20.775E | | | | | | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1013 | 19 JUN 1974 | 02:45:18.3 | 39.198N | 22.187E | | | | | | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1014 | 15 JUL 1974 | 00:25:37.4 | 39.252N | 22.139E | | | | | | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1015 | 15 JUL 1974 | 15:29:02.7 | 38.747N | 22.260E | | | | | | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1016 | 2 JUL 1975 | 02:19:45.6 | 38.307N | 21.574E | | | | | 46 | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>20 STATION RECORDINGS USED IN SOLUTION |
| 1017 | 7 AUG 1975 | 01:00:57.8 | 38.308N | 21.644E | | | 4.20 | | 58 | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>33 STATION RECORDINGS USED IN SOLUTION |
| 1018 | 22 NOV 1975 | 18:35:07.3 | 38.303N | 21.535E | | | | | 39 | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>64 STATION RECORDINGS USED IN SOLUTION |
| 1019 | 25 DEC 1975 | 09:45:22.0 | 38.303N | 21.505E | | | | | 25 | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 1020 | 31 DEC 1975 | 12:13:42.5 | 38.361N | 21.854E | | | | | 50 | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>21 STATION RECORDINGS USED IN SOLUTION |
| 1021 | 31 DEC 1975 | 22:49:39.7 | 38.303N | 21.511E | | | | | 70 | 66 | | | IS ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 1022 | 8 MAY 1951 | 19:09:29.0 | 39.500N | 21.500E | | V | | | | 67 | | | IS ORIGINAL DATA SOURCE = ISS |
| 1023 | 5 JUN 1954 | 14:05:32.0 | 39.500N | 21.500E | | | | | | 67 | | | IS DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |
| 1024 | 13 MAR 1956 | 20:21:14.0 | 39.500N | 21.500E | | | | | | 67 | | | IS ORIGINAL DATA SOURCE = BCIS |
| 1025 | 25 APR 1956 | 08:01:00.0 | 39.200N | 22.200E | | V | | | | 67 | | | IS ORIGINAL DATA SOURCE = BCIS |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1026 | 19 JAN 1962 | 19:38:00.0 | 38.500N | 22.100E | | VII- | 5.38 | | | 67 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = ATH<br>MAGNITUDE AUTHORITY = ATH |
| 1027 | 20 APR 1963 | 00:43:56.0 | 38.700N | 20.800E | | IV | | | 40 | 67 | IS | ORIGINAL DATA SOURCE = BCIS |
| 1028 | 8 FEB 1966 | 17:22:37.4 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1029 | 22 FEB 1966 | 10:05:30.0 | 39.400N | 21.100E | | | | | | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1030 | 14 MAR 1966 | 14:16:05.0 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1031 | 17 APR 1966 | 20:45:18.4 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1032 | 30 JUN 1966 | 02:08:05.0 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1033 | 14 AUG 1966 | 02:39:38.8 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |
| 1034 | 14 AUG 1966 | 03:14:23.0 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1035 | 14 AUG 1966 | 23:48:32.0 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1036 | 3 NOV 1966 | 22:48:40.8 | 39.200N | 22.200E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1037 | 15 NOV 1966 | 22:12:05.8 | 38.700N | 20.800E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1038 | 27 NOV 1966 | 06:05:10.6 | 39.280N | 20.930E | | | | | 76 | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1039 | 24 DEC 1966 | 10:17:34.3 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1040 | 1 MAY 1967 | 09:47:40.0 | 39.460N | 21.230E | | | | | 10 | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>35 STATION RECORDINGS USED IN SOLUTION |
| 1041 | 8 SEP 1967 | 01:58:35.0 | 39.500N | 21.500E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1042 | 29 DEC 1968 | 05:45:05.0 | 38.500N | 22.100E | | | 2.80 | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1043 | 15 NOV 1969 | 11:38:01.0 | 38.600N | 22.200E | | | | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1044 | 26 FEB 1970 | 11:27:58.0 | 39.500N | 21.500E | | | 3.40 | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1045 | 11 APR 1970 | 22:06:22.0 | 38.900N | 22.300E | | | | | 48 | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1046 | 18 APR 1970 | 11:44:04.0 | 38.300N | 21.600E | | | 3.40 | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1047 | 30 JUN 1970 | 23:06:19.0 | 38.700N | 20.800E | | | | | | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1048 | 2 JUL 1970 | 01:38:20.6 | 38.310N | 21.700E | | | | | | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1049 | 25 JUL 1970 | 14:50:29.9 | 38.300N | 21.440E | | | | | | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1050 | 11 JUN 1971 | 00:17:14.0 | 38.400N | 21.100E | | | 3.20 | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 1051 | 24 NOV 1972 | 02:42:54.0 | 38.900N | 22.300E | | | 2.50 | | | 67 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 1052 | 14 SEP 1973 | 04:57:01.9 | 38.967N | 22.302E | | | | | | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1053 | 18 NOV 1974 | 19:23:51.6 | 38.664N | 20.818E | | | | | | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1054 | 7 DEC 1974 | 12:14:20.1 | 38.293N | 21.559E | | | | | 31 | 67 | IS | ORIGINAL DATA SOURCE = ISC<br>16 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1055 | 26 MAY 1975 | 22:55:54.2 | 38.362N | 21.181E | | | | | | 67 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1056 | 30 JUN 1975 | 13:42:16.4 | 38.319N | 21.743E | | | | | 6 | 67 | | IS | ORIGINAL DATA SOURCE = ISC<br>16 STATION RECORDINGS USED IN SOLUTION |
| 1057 | 8 AUG 1975 | 08:20:11.0 | 38.379N | 21.926E | | | | | 36 | 67 | | IS | ORIGINAL DATA SOURCE = ISC<br>24 STATION RECORDINGS USED IN SOLUTION |
| 1058 | 29 SEP 1975 | 12:35:41.5 | 39.071N | 22.266E | | | | | | 67 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1059 | 1 JAN 1966 | 20:12:02.4 | 39.500N | 21.400E | | | | | | 68 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1060 | 9 AUG 1966 | 20:20:48.7 | 39.500N | 21.400E | | | 4.00 | | | 68 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1061 | 25 DEC 1966 | 05:54:03.3 | 38.300N | 21.700E | | | | | | 68 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1062 | 1 MAY 1967 | 16:40:06.0 | 39.510N | 21.460E | | | 4.30 | | 38 | 68 | | IS | ORIGINAL DATA SOURCE = ISC<br>31 STATION RECORDINGS USED IN SOLUTION |
| 1063 | 22 JUN 1967 | 07:54:20.0 | 39.500N | 21.400E | | | | | | 68 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1064 | 25 JUL 1968 | 04:16:14.5 | 39.500N | 21.380E | | | | | | 68 | | IS | ORIGINAL DATA SOURCE = ISC<br>16 STATION RECORDINGS USED IN SOLUTION |
| 1065 | 11 SEP 1971 | 02:03:11.5 | 38.869N | 22.313E | | | 4.50 | | 5 | 68 | | IS | ORIGINAL DATA SOURCE = ISC<br>58 STATION RECORDINGS USED IN SOLUTION |
| 1066 | 2 MAR 1972 | 10:51:50.9 | 38.336N | 21.823E | | | | | | 68 | | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 1067 | 15 JUN 1972 | 17:32:57.8 | 38.407N | 21.985E | | | | | | 68 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1068 | 8 NOV 1972 | 19:44:00.5 | 38.360N | 21.897E | | | | | | 68 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1069 | 28 JAN 1973 | 00:09:04.5 | 38.623N | 22.225E | | | | | | 68 | | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 1070 | 15 JUN 1973 | 03:36:59.0 | 38.357N | 21.901E | | | | | | 68 | | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1071 | 30 JUL 1973 | 18:40:23.5 | 38.689N | 22.267E | | | | | | 68 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1072 | 5 JAN 1974 | 08:45:19.7 | 38.705N | 22.274E | | | | | | 68 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1073 | 31 JAN 1974 | 08:30:33.4 | 39.308N | 22.118E | | | | | 6 | 68 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1074 | 7 AUG 1974 | 19:33:28.3 | 38.904N | 22.313E | | | | | | 68 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1075 | 22 NOV 1974 | 21:44:03.7 | 38.343N | 21.852E | | | | | | 68 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 1076 | 31 AUG 1975 | 00:11:13.0 | 38.324N | 21.809E | | | | | | 68 | IS | ORIGINAL DATA SOURCE = ISC<br>16 STATION RECORDINGS USED IN SOLUTION |
| 1077 | 8 OCT 1957 | 07:00:45.0 | 39.000N | 20.750E | | VI | 5.38 | | | 69 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 1078 | 18 OCT 1957 | 01:50:49.0 | 38.370N | 21.940E | | | | | | 69 | IS | ORIGINAL DATA SOURCE = ISS |
| 1079 | 23 FEB 1960 | 07:18:06.0 | 39.000N | 20.750E | | VII | | | | 69 | IS | ISC EFFECTS CODE = FELT<br>ORIGINAL DATA SOURCE = BCIS |
| 1080 | 29 NOV 1965 | 14:34:07.9 | 39.400N | 22.000E | | | | | | 69 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1081 | 22 AUG 1966 | 05:20:30.0 | 39.500N | 21.750E | | | | | | 69 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>1 STATION RECORDINGS USED IN SOLUTION |
| 1082 | 21 OCT 1966 | 23:48:12.7 | 39.400N | 22.000E | | | | | | 69 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1083 | 19 FEB 1969 | 14:33:15.7 | 38.310N | 21.790E | | | | | | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1084 | 12 APR 1969 | 08:28:48.0 | 38.400N | 22.000E | | | | | | 69 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1085 | 8 OCT 1969 | 02:04:21.8 | 38.300N | 21.730E | | | | | | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 1086 | 19 JUN 1970 | 06:51:28.0 | 38.400N | 22.000E | | | 4.20 | | 33 | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>25 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1087 | 24 NOV 1972 | 01:35:27.5 | 38.833N | 22.318E | | | 4.20 | | 37 | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>75 STATION RECORDINGS USED IN SOLUTION |
| 1088 | 5 NOV 1973 | 15:59:17.3 | 38.772N | 20.751E | | | | | | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1089 | 1 JUL 1974 | 06:12:49.5 | 38.913N | 22.327E | | | | | 36 | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 1090 | 14 JUL 1974 | 20:17:25.5 | 38.817N | 22.321E | | | 3.70 | | 90 | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>21 STATION RECORDINGS USED IN SOLUTION |
| 1091 | 24 NOV 1975 | 00:03:24.2 | 38.330N | 21.844E | | | | | | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1092 | 31 DEC 1975 | 19:20:14.1 | 38.327N | 21.838E | | | | | | 69 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 1093 | 23 JAN 1954 | 20:14:46.0 | 38.750N | 20.750E | | IV | | | | 70 | IS | ORIGINAL DATA SOURCE = BCIS |
| 1094 | 19 MAY 1958 | 18:17:52.0 | 38.750N | 20.750E | | IV | | | | 70 | IS | ORIGINAL DATA SOURCE = BCIS |
| 1095 | 5 MAY 1962 | 22:28:24.0 | 38.750N | 20.750E | | | | | | 70 | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 1096 | 15 JUN 1966 | 01:30:27.6 | 38.750N | 20.750E | | | | | | 70 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1097 | 4 JUL 1966 | 19:23:54.8 | 38.750N | 20.750E | | | | | | 70 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1098 | 4 MAY 1967 | 04:46:19.1 | 39.530N | 21.520E | | | 4.40 | | 55 | 70 | IS | ORIGINAL DATA SOURCE = ISC<br>39 STATION RECORDINGS USED IN SOLUTION |
| 1099 | 3 DEC 1968 | 02:30:29.0 | 39.100N | 22.300E | | | | | | 70 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH |
| 1100 | 19 DEC 1969 | 08:33:57.1 | 38.450N | 22.090E | | | | | 4 | 70 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1101 | 18 MAR 1970 | 13:23:13.0 | 38.300N | 21.300E | | | | | | 70 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1102 | 24 AUG 1972 | 02:30:45.1 | 39.413N | 22.005E | | | | | | 70 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1103 | 12 MAR 1973 | 15:14:22.3 | 38.275N | 21.646E | | | | | | 70 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE       TIME(GMT)      LAT       LONG    SL INTEN  MAG SM   H  (IS G S          L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                              (MM)            (KM)(KM)
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1104  11 APR 1973  22:26:41.0  39.237N  20.849E                             70   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

1105  12 SEP 1974  13:50:58.8  39.219N  22.227E                             70   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      4 STATION RECORDINGS USED IN SOLUTION

1106  24 MAR 1975  15:19:44.2  39.474N  21.208E            3.80     53  70   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     22 STATION RECORDINGS USED IN SOLUTION

1107  26 JUL 1975  04:13:57.6  38.333N  21.882E                             70   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      9 STATION RECORDINGS USED IN SOLUTION

1108   7 APR 1960  19:44:41.0  38.500N  20.900E    V                        71   IS ORIGINAL DATA SOURCE =  BCIS

1109   3 MAY 1966  05:01:45.4  39.500N  21.250E                             71   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      2 STATION RECORDINGS USED IN SOLUTION

1110   4 JAN 1967  07:24:54.8  38.300N  21.800E                             71   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      4 STATION RECORDINGS USED IN SOLUTION

1111   1 MAY 1967  09:50:08.2  39.510N  21.300E            4.80     33  71   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    110 STATION RECORDINGS USED IN SOLUTION

1112   7 JUN 1967  09:34:48.4  39.390N  21.000E                             71   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

1113   1 AUG 1968  15:45:33.0  39.200N  20.800E            3.60             71   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      4 STATION RECORDINGS USED IN SOLUTION

1114   3 JUL 1969  09:42:02.0  38.410N  22.050E            4.50     28  71   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     71 STATION RECORDINGS USED IN SOLUTION

1115   8 MAY 1970  22:10:55.1  38.610N  22.260E                     12  71   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      6 STATION RECORDINGS USED IN SOLUTION

1116  12 MAY 1970  08:53:56.0  38.300N  21.800E            3.40         71   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  ATH
                                                                                      7 STATION RECORDINGS USED IN SOLUTION

1117  16 SEP 1971  17:56:25.5  38.320N  21.874E                             71   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      8 STATION RECORDINGS USED IN SOLUTION

1118  30 MAY 1972  02:39:16.7  39.298N  20.891E                             71   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      4 STATION RECORDINGS USED IN SOLUTION

1119   6 JUL 1972  10:48:48.6  39.158N  20.780E                             71   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      4 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1120 | 31 AUG 1973 | 05:51:03.7 | 38.744N | 22.328E | | | | | | 71 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1121 | 1 JUL 1975 | 04:20:20.3 | 38.354N | 21.956E | | | | | | 71 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1122 | 14 JUL 1975 | 01:54:41.1 | 38.285N | 21.747E | | | | | 64 | 71 | | IS | ORIGINAL DATA SOURCE = ISC<br>29 STATION RECORDINGS USED IN SOLUTION |
| 1123 | 7 AUG 1975 | 07:57:24.3 | 38.277N | 21.708E | | | | | | 71 | | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 1124 | 14 DEC 1975 | 04:14:14.2 | 38.266N | 21.421E | | | | | | 71 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1125 | 14 JUN 1954 | 20:06:23.0 | 38.250N | 21.500E | | V | 5.00 | | | 72 | | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 1126 | 21 FEB 1962 | 12:24:25.0 | 38.250N | 21.500E | | V | | | | 72 | | IS | ORIGINAL DATA SOURCE = BCIS |
| 1127 | 29 APR 1962 | 09:25:39.0 | 38.400N | 21.000E | | IV | | | | 72 | | IS | ORIGINAL DATA SOURCE = BCIS |
| 1128 | 29 APR 1962 | 18:01:10.0 | 38.400N | 21.000E | | IV | | | | 72 | | IS | ORIGINAL DATA SOURCE = BCIS |
| 1129 | 17 MAR 1963 | 14:17:18.0 | 39.400N | 21.000E | | VII | 5.10 | | | 72 | | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 1130 | 22 JUL 1964 | 21:26:16.0 | 38.250N | 21.500E | | | | | | 72 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1131 | 12 SEP 1964 | 05:16:40.0 | 38.250N | 21.500E | | | | | | 72 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1132 | 24 JUN 1965 | 23:36:14.5 | 39.460N | 21.950E | | | | | | 72 | | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 1133 | 11 MAY 1966 | 01:07:27.6 | 39.400N | 21.000E | | | | | | 72 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1134 | 3 MAY 1967 | 18:41:47.2 | 39.530N | 21.340E | | | 4.80 | | 37 | 72 | | IS | ORIGINAL DATA SOURCE = ISC<br>117 STATION RECORDINGS USED IN SOLUTION |
| 1135 | 9 OCT 1967 | 10:45:16.8 | 38.300N | 21.220E | | | 4.30 | | 8 | 72 | | IS | ORIGINAL DATA SOURCE = ISC<br>18 STATION RECORDINGS USED IN SOLUTION |
| 1136 | 4 MAR 1969 | 01:12:37.0 | 38.650N | 22.300E | | | | | 7 | 72 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1137 | 26 MAR 1970 | 06:20:18.0 | 38.900N | 20.700E | | | | | 72 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1138 | 8 MAY 1970 | 18:30:42.7 | 38.670N | 22.300E | | | 4.40 | 58 | 72 | IS | ORIGINAL DATA SOURCE = ISC<br>70 STATION RECORDINGS USED IN SOLUTION |
| 1139 | 13 APR 1972 | 06:50:02.8 | 39.252N | 20.837E | | | | | 72 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1140 | 16 JUN 1973 | 04:15:11.6 | 38.393N | 22.047E | | | | 5 | 72 | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 1141 | 24 NOV 1973 | 01:43:35.6 | 39.209N | 22.264E | | | | | 72 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1142 | 15 JUL 1974 | 21:14:51.9 | 39.116N | 22.313E | | | | | 72 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1143 | 26 JUL 1975 | 02:45:31.2 | 38.304N | 21.846E | | | 3.80 | 50 | 72 | IS | ORIGINAL DATA SOURCE = ISC<br>32 STATION RECORDINGS USED IN SOLUTION |
| 1144 | 30 APR 1954 | 13:02:36.0 | 39.300N | 22.200E | | IX | 6.87 | | 73 | IS | ORIGINAL DATA SOURCE = ISS<br>MAGNITUDE AUTHORITY = PAS |
| 1145 | 4 MAY 1954 | 16:43:20.0 | 39.300N | 22.200E | | VII | | | 73 | IS | ORIGINAL DATA SOURCE = ISS |
| 1146 | 4 MAY 1954 | 16:45:27.0 | 39.300N | 22.200E | | VI | | | 73 | IS | ORIGINAL DATA SOURCE = ISS |
| 1147 | 25 MAY 1954 | 22:03:32.0 | 39.300N | 22.200E | | VI | | | 73 | IS | ORIGINAL DATA SOURCE = ISS |
| 1148 | 24 OCT 1957 | 22:45:12.0 | 39.250N | 22.250E | | VI | | | 73 | IS | ORIGINAL DATA SOURCE = BCIS |
| 1149 | 22 JUL 1966 | 00:55:28.7 | 38.500N | 22.200E | | | 3.90 | | 73 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1150 | 21 OCT 1966 | 19:08:01.0 | 39.250N | 22.250E | | | | | 73 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1151 | 9 JAN 1967 | 20:34:49.0 | 39.300N | 22.200F | | | | | 73 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1152 | 22 NOV 1967 | 07:21:48.0 | 39.250N | 22.250E | | | 3.20 | | 73 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1153 | 25 DEC 1967 | 07:03:56.0 | 38.500N | 22.200E | | | | | 73 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1170 | 1 NOV 1967 | 07:04:32.1 | 38.370N | 22.040E | | | | | 80 | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1171 | 11 NOV 1969 | 22:59:37.0 | 38.300N | 21.900E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1172 | 3 DEC 1970 | 11:29:36.9 | 38.410N | 22.100E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1173 | 2 MAR 1972 | 07:10:56.5 | 38.322N | 21.954E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1174 | 3 MAY 1972 | 12:30:23.0 | 39.268N | 20.815E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1175 | 27 APR 1973 | 08:30:02.8 | 38.827N | 22.383E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1176 | 29 JAN 1974 | 15:12:44.8 | 38.290N | 21.865E | | | 4.40 | | 34 | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>66 STATION RECORDINGS USED IN SOLUTION |
| 1177 | 3 DEC 1974 | 05:20:39.6 | 39.155N | 20.[illegible]4E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1178 | 27 MAR 1975 | 02:24:48.9 | 38.251N | 21.730E | | | | | 13 | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>16 STATION RECORDINGS USED IN SOLUTION |
| 1179 | 27 MAY 1975 | 07:21:03.0 | 39.052N | 20.700E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1180 | 12 SEP 1975 | 00:36:43.9 | 39.434N | 22.038E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1181 | 20 SEP 1975 | 23:12:19.4 | 38.353N | 22.009E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 1182 | 3 DEC 1975 | 19:00:28.4 | 39.057N | 22.357E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>13 STATION RECORDINGS USED IN SOLUTION |
| 1183 | 31 DEC 1975 | 06:46:26.9 | 38.260N | 21.789E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 1184 | 6 JUL 1925 | 12:15:55.0 | 38.250N | 21.750E | | | 6.50 | | 120 | 75 | | IS | QUALITY = -AAA<br>ORIGINAL DATA SOURCE = GUTE<br>MAGNITUDE AUTHORITY = PAS |
| 1185 | 19 FEB 1960 | 21:36:08.0 | 38.250N | 21.750E | | V | | | | 75 | | IS | ORIGINAL DATA SOURCE = BCIS |
| 1186 | 6 MAY 1963 | 19:30:29.0 | 39.100N | 20.700E | | V | 5.10 | | | 75 | | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = NUR |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | L O C A T I O N A N D C O M M E N T S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1154 | 18 JUL 1968 | 22:44:30.0 | 38.800N | 20.700E | | | 3.60 | | | 73 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1155 | 11 APR 1970 | 19:47:54.9 | 39.000N | 22.360E | | | | | 61 | 73 | | IS | ORIGINAL DATA SOURCE = ISC<br>20 STATION RECORDINGS USED IN SOLUTION |
| 1156 | 30 JUN 1970 | 17:52:30.4 | 38.800N | 20.700E | | | | | | 73 | | IS | ORIGINAL DATA SOURCE = ISC<br>31 STATION RECORDINGS USED IN SOLUTION |
| 1157 | 3 NOV 1970 | 15:11:26.7 | 38.860N | 20.690E | | | | | | 73 | | IS | ORIGINAL DATA SOURCE = ISC<br>29 STATION RECORDINGS USED IN SOLUTION |
| 1158 | 30 MAY 1971 | 00:34:13.9 | 38.365N | 21.038E | | | | | | 73 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1159 | 12 MAY 1973 | 11:21:01.9 | 38.841N | 22.365E | | | | | 3 | 73 | | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1160 | 15 DEC 1974 | 20:06:00.6 | 39.195N | 20.779E | | | | | | 73 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1161 | 2 AUG 1975 | 01:57:28.5 | 38.317N | 21.927E | | | | | | 73 | | IS | ORIGINAL DATA SOURCE = ISC<br>10 STATION RECORDINGS USED IN SOLUTION |
| 1162 | 11 NOV 1975 | 14:01:57.0 | 38.312N | 21.915E | | | 4.00 | | | 73 | | IS | ORIGINAL DATA SOURCE = ISC<br>18 STATION RECORDINGS USED IN SOLUTION |
| 1163 | 15 MAR 1955 | 18:43:00.0 | 38.300N | 21.900E | | V | | | | 74 | | IS | ISC EFFECTS CODE = FELT<br>ORIGINAL DATA SOURCE = BCIS |
| 1164 | 9 NOV 1957 | 23:55:52.0 | 38.400N | 22.100E | | VI | 5.13 | | | 74 | | IS | ISC EFFECTS CODE = FELT<br>ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 1165 | 20 FEB 1965 | 22:47:08.6 | 38.400N | 22.100E | | | 4.40 | | 6 | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>21 STATION RECORDINGS USED IN SOLUTION |
| 1166 | 4 JAN 1967 | 05:58:52.5 | 38.370N | 22.040E | | | 5.30 | | 1 | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>172 STATION RECORDINGS USED IN SOLUTION |
| 1167 | 4 JAN 1967 | 21:42:14.9 | 38.400N | 22.100E | | | | | | 74 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1168 | 3 SEP 1967 | 22:38:35.0 | 38.270N | 21.810E | | | 4.30 | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 1169 | 10 OCT 1967 | 01:28:17.3 | 38.300N | 21.160E | | | | | | 74 | | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE        TIME(GMT)       LAT       LONG    SL INTEN  MAG SP   H  CIS G S          L O C A T I O N     A N D     C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                              (MM)            (KM)(KM)
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1187  13 JUN 1964  19:09:39.0  38.250N  21.750E                               75   IS DATA OBTAINED VIA ISC
                                                                                      ORIGINAL DATA SOURCE =  ATH
                                                                                        5 STATION RECORDINGS USED IN SOLUTION

1188   9 JUL 1964  14:41:00.0  38.250N  21.750E                               75   IS DATA OBTAINED VIA ISC
                                                                                      ORIGINAL DATA SOURCE =  ATH
                                                                                        2 STATION RECORDINGS USED IN SOLUTION

1189  23 FEB 1965  19:53:58.0  38.250N  21.750E                               75   IS DATA OBTAINED VIA ISC
                                                                                      ORIGINAL DATA SOURCE =  ATH
                                                                                        4 STATION RECORDINGS USED IN SOLUTION

1190  21 APR 1965  12:48:03.0  38.250N  21.750E                               75   IS DATA OBTAINED VIA ISC
                                                                                      ORIGINAL DATA SOURCE =  ATH
                                                                                        2 STATION RECORDINGS USED IN SOLUTION

1191  31 AUG 1966  14:54:15.3  38.600N  22.300E                               75   IS DATA OBTAINED VIA ISC
                                                                                      ORIGINAL DATA SOURCE =  ATH
                                                                                        3 STATION RECORDINGS USED IN SOLUTION

1192  17 OCT 1967  13:02:26.0  38.250N  21.750E               3.40        50  75   IS DATA OBTAINED VIA ISC
                                                                                      ORIGINAL DATA SOURCE =  ATH
                                                                                        3 STATION RECORDINGS USED IN SOLUTION

1193   4 FEB 1968  00:31:13.0  39.090N  20.700E                               75   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        5 STATION RECORDINGS USED IN SOLUTION

1194  18 MAY 1970  01:36:34.0  38.700N  20.700E                               75   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        4 STATION RECORDINGS USED IN SOLUTION

1195  25 JUL 1970  17:21:18.0  38.700N  20.700E                               75   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        7 STATION RECORDINGS USED IN SOLUTION

1196   2 DEC 1971  06:00:28.6  39.281N  22.241E               4.30            75   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       18 STATION RECORDINGS USED IN SOLUTION

1197   4 MAR 1972  14:41:28.8  38.260N  21.798E                               75   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       11 STATION RECORDINGS USED IN SOLUTION

1198  10 MAY 1973  04:10:29.0  38.600N  22.300E                               75   IS DATA OBTAINED VIA ISC
                                                                                      ORIGINAL DATA SOURCE =  ATH
                                                                                        0 STATION RECORDINGS USED IN SOLUTION

1199  23 JUL 1973  05:19:16.2  38.238N  21.336E                               75   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        6 STATION RECORDINGS USED IN SOLUTION

1200   4 JAN 1974  05:36:04.7  38.300N  21.139E                               75   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        9 STATION RECORDINGS USED IN SOLUTION

1201  24 JUN 1974  10:57:08.9  39.549N  21.761E                               75   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        4 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1202 | 7 SEP 1974 | 04:44:54.3 | 38.339N | 22.015E | | | | | | 75 | I | S | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1203 | 3 JUN 1975 | 06:21:58.8 | 38.271N | 21.858E | | | | | 1 | 75 | I | S | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1204 | 29 SEP 1975 | 10:50:29.0 | 39.104N | 22.358E | | | | | | 75 | I | S | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1205 | 4 OCT 1975 | 04:55:22.9 | 39.013N | 22.385E | | | | | | 75 | I | S | ORIGINAL DATA SOURCE = ISC<br>21 STATION RECORDINGS USED IN SOLUTION |
| 1206 | 16 NOV 1975 | 18:05:55.4 | 38.352N | 22.039E | | | | | 11 | 75 | I | S | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1207 | 25 MAY 1955 | 00:55:23.0 | 38.250N | 21.250E | | V | | | | 76 | I | S | ORIGINAL DATA SOURCE = BCIS |
| 1208 | 30 DEC 1956 | 18:24:23.0 | 38.300N | 21.100E | | V | 5.13 | | | 76 | I | S | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 1209 | 6 MAY 1963 | 19:30:38.0 | 39.370N | 20.890E | | | | | 105 | 76 | I | S | ORIGINAL DATA SOURCE = ISS |
| 1210 | 20 SEP 1964 | 00:48:54.0 | 38.250N | 21.250E | | | | | | 76 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1211 | 21 NOV 1966 | 20:06:32.0 | 38.320N | 21.990E | | | | | 16 | 76 | I | S | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1212 | 15 DEC 1966 | 15:42:50.0 | 38.250N | 21.250E | | | | | | 76 | I | S | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1213 | 5 MAY 1967 | 06:26:37.9 | 39.560N | 21.290E | | | 4.70 | | 57 | 76 | I | S | ORIGINAL DATA SOURCE = ISC<br>80 STATION RECORDINGS USED IN SOLUTION |
| 1214 | 9 MAY 1967 | 20:44:57.0 | 39.500N | 21.100E | | | | | | 76 | I | S | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1215 | 9 JUN 1974 | 02:27:29.3 | 38.906N | 20.650E | | | | | | 76 | I | S | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1216 | 19 JUN 1974 | 07:04:00.6 | 39.582N | 21.495E | | | | | 2 | 76 | I | S | ORIGINAL DATA SOURCE = ISC<br>17 STATION RECORDINGS USED IN SOLUTION |
| 1217 | 26 JUL 1975 | 21:15:19.5 | 38.256N | 21.825E | | | | | 10 | 76 | I | S | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1218 | 31 DEC 1975 | 06:40:08.1 | 38.312N | 21.979E | | | | | | 76 | I | S | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1219 | 4 DEC 1954 | 22:56:29.0 | 38.500N | 20.800E | | | | | | 77 | IS | ORIGINAL DATA SOURCE = BCIS |
| 1220 | 11 NOV 1960 | 05:31:31.9 | 39.300N | 20.800E | | | | | 43 | 77 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |
| 1221 | 10 JAN 1962 | 02:11:50.0 | 38.500N | 22.250E | | VI | 4.63 | | | 77 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 1222 | 17 SEP 1964 | 22:51:57.0 | 38.500N | 22.250E | | | | | | 77 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1223 | 18 SEP 1964 | 04:00:44.0 | 38.500N | 22.250E | | | | | | 77 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1224 | 16 OCT 1964 | 11:22:04.0 | 38.500N | 22.250E | | | 4.70 | | | 77 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1225 | 19 JAN 1965 | 04:35:00.0 | 38.500N | 22.250E | | | | | | 77 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1226 | 31 MAR 1965 | 12:01:11.7 | 38.470N | 22.230E | | | 4.60 | | 78 | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>27 STATION RECORDINGS USED IN SOLUTION |
| 1227 | 13 JUL 1965 | 04:14:35.4 | 38.500N | 22.250E | | | | | | 77 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1228 | 26 AUG 1965 | 08:59:34.0 | 38.500N | 22.250E | | | 3.40 | | | 77 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1229 | 5 MAR 1966 | 20:47:29.0 | 38.500N | 22.250E | | | | | | 77 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1230 | 5 MAY 1967 | 20:18:32.0 | 39.560N | 21.250E | | | | | 20 | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 1231 | 5 AUG 1967 | 15:17:58.0 | 39.300N | 20.800E | | | | | | 77 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1232 | 16 JUL 1970 | 22:29:40.0 | 39.300N | 20.800E | | | | | | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1233 | 22 FEB 1972 | 16:15:38.0 | 38.421N | 22.169E | | | | | 37 | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>1[illegible] STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | CIS (KM) | G S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1234 | 22 JUN 1972 | 22:09:57.0 | 38.549N | 22.289E | | | | | | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1235 | 9 SEP 1973 | 02:13:33.0 | 39.287N | 22.274E | | | | | | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 1236 | 15 SEP 1974 | 18:56:27.3 | 39.503N | 21.095E | | | | | | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1237 | 19 DEC 1974 | 07:05:15.5 | 39.174N | 20.710E | | | | | | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1238 | 24 JAN 1975 | 07:38:41.1 | 38.263N | 21.894E | | | 4.10 | | 41 | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>20 STATION RECORDINGS USED IN SOLUTION |
| 1239 | 19 MAY 1975 | 20:27:51.9 | 38.660N | 20.695E | | | | | | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1240 | 26 JUL 1975 | 04:25:25.9 | 38.228N | 21.755E | | | | | 41 | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>19 STATION RECORDINGS USED IN SOLUTION |
| 1241 | 13 AUG 1975 | 16:13:06.2 | 39.373N | 20.886E | | | | | | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1242 | 7 OCT 1975 | 01:27:50.9 | 38.238N | 21.802E | | | | | 42 | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>14 STATION RECORDINGS USED IN SOLUTION |
| 1243 | 31 DEC 1975 | 18:19:18.6 | 38.213N | 21.381E | | | | | 133 | 77 | IS | ORIGINAL DATA SOURCE = ISC<br>11 STATION RECORDINGS USED IN SOLUTION |
| 1244 | 1 MAR 1941 | 03:52:48.0 | 39.500N | 22.000E | | | 6.25 | | | 78 | IS | ORIGINAL DATA SOURCE = GUTE<br>MAGNITUDE AUTHORITY = PAS |
| 1245 | 16 APR 1947 | 13:22:06.0 | 38.200N | 21.500E | | | | | | 78 | IS | ORIGINAL DATA SOURCE = ISS |
| 1246 | 17 JAN 1948 | 02:26:23.0 | 38.200N | 21.500E | | | | | | 78 | IS | ORIGINAL DATA SOURCE = ISS |
| 1247 | 30 APR 1954 | 13:02:36.0 | 39.500N | 22.000E | | | 7.00 | | | 78 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS<br>MAGNITUDE AUTHORITY = PAS |
| 1248 | 30 APR 1954 | 19:33:30.0 | 39.500N | 22.000E | | | | | | 78 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |
| 1249 | 4 MAY 1954 | 16:43:20.0 | 39.500N | 22.000E | | VII | 5.37 | | | 78 | IS | DATA OBTAINED VIA ISS<br>ORIGINAL DATA SOURCE = ATH<br>MAGNITUDE AUTHORITY = ATH |
| 1250 | 4 MAY 1954 | 16:43:22.0 | 39.500N | 22.000E | | | | | | 78 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1251 | 25 MAY 1954 | 22:03:34.0 | 39.500N | 22.000E | | | | | | 78 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |
| 1252 | 5 AUG 1954 | 03:48:22.0 | 39.500N | 22.000E | | VI | 5.25 | | | 78 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 1253 | 19 MAY 1957 | 03:20:44.0 | 39.250N | 20.750E | | V | | | | 78 | IS | ORIGINAL DATA SOURCE = BCIS |
| 1254 | 19 MAY 1957 | 13:43:12.0 | 39.250N | 20.750E | | | | | | 78 | IS | QUALITY = REPT<br>ORIGINAL DATA SOURCE = BCIS |
| 1255 | 31 AUG 1966 | 10:15:04.1 | 39.250N | 20.750E | | | | | | 78 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1256 | 17 OCT 1966 | 12:59:45.3 | 39.400N | 20.900E | | | | | | 78 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1257 | 26 DEC 1966 | 13:01:01.6 | 39.250N | 20.750E | | | | | | 78 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>2 STATION RECORDINGS USED IN SOLUTION |
| 1258 | 28 MAR 1967 | 22:13:50.9 | 39.250N | 20.750E | | | 3.50 | | | 78 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1259 | 13 OCT 1967 | 19:28:57.3 | 38.200N | 21.600E | | | | | 58 | 78 | IS | ORIGINAL DATA SOURCE = ISC<br>16 STATION RECORDINGS USED IN SOLUTION |
| 1260 | 22 DEC 1968 | 22:10:21.2 | 39.150N | 22.370E | | | | | 8 | 78 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1261 | 24 MAR 1969 | 06:02:58.0 | 38.450N | 22.220E | | | | | | 78 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1262 | 27 JAN 1970 | 20:44:30.0 | 39.250N | 20.750E | | | 3.50 | | | 78 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>3 STATION RECORDINGS USED IN SOLUTION |
| 1263 | 17 JUN 1970 | 05:59:58.0 | 38.380N | 22.140E | | | 4.40 | | 3 | 78 | IS | ORIGINAL DATA SOURCE = ISC<br>48 STATION RECORDINGS USED IN SOLUTION |
| 1264 | 19 SEP 1970 | 07:02:34.8 | 38.240N | 21.850E | | | | | | 78 | IS | ORIGINAL DATA SOURCE = ISC<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1265 | 7 MAY 1971 | 01:40:00.9 | 38.356N | 22.100E | | | | | | 78 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1266 | 14 APR 1972 | 23:01:46.1 | 39.231N | 20.731E | | | | | | 78 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE        TIME(GMT)      LAT      LONG     SL INTEN  MAG SM   H  DIS Q S       L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR   HR-MIN-SEC                            (MM)            (KM)(KM)
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1267  23 MAR 1973   03:37:59.0  38.300N  22.000E                        78    IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                   0 STATION RECORDINGS USED IN SOLUTION

1268  17 NOV 1973   11:04:57.3  39.515N  21.105E                        78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                   7 STATION RECORDINGS USED IN SOLUTION

1269  20 MAR 1974   04:34:41.4  39.110N  22.390E                        78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                  10 STATION RECORDINGS USED IN SOLUTION

1270  28 JUL 1974   05:37:41.7  38.406N  22.174E                        78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                  17 STATION RECORDINGS USED IN SOLUTION

1271  11 AUG 1974   10:41:06.4  38.689N  22.387E                        78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                   6 STATION RECORDINGS USED IN SOLUTION

1272  30 SEP 1974   08:23:00.1  38.312N  22.018E            4.20        78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                  37 STATION RECORDINGS USED IN SOLUTION

1273  31 JAN 1975   23:17:48.7  38.850N  20.639E                        78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                  11 STATION RECORDINGS USED IN SOLUTION

1274   4 AUG 1975   06:56:50.1  38.215N  21.730E                        78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                   9 STATION RECORDINGS USED IN SOLUTION

1275  16 OCT 1975   17:45:49.3  38.277N  21.946E            4.10    40  78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                  40 STATION RECORDINGS USED IN SOLUTION

1276  23 NOV 1975   07:33:39.4  38.331N  22.058E                        78    IS ORIGINAL DATA SOURCE =  ISC
                                                                                   5 STATION RECORDINGS USED IN SOLUTION

1277  24 AUG 1952   15:19:32.0  39.100N  22.400E     V                  79    IS ORIGINAL DATA SOURCE =  BCIS
1278  16 SEP 1953   12:03:50.0  38.600N  20.700E     III                79    IS ORIGINAL DATA SOURCE =  BCIS
1279   2 MAY 1967   01:27:20.4  39.560N  21.200E            4.40    35  79    IS ORIGINAL DATA SOURCE =  ISC
                                                                                  45 STATION RECORDINGS USED IN SOLUTION

1280   5 FEB 1968   07:22:27.0  38.700N  22.400E            3.00    50  79    IS DATA OBTAINED VIA ISC
                                                                                 ORIGINAL DATA SOURCE =  ATH
                                                                                   4 STATION RECORDINGS USED IN SOLUTION

1281  17 AUG 1970   11:05:58.0  38.200N  21.400E                        79    IS ORIGINAL DATA SOURCE =  ISC
                                                                                   5 STATION RECORDINGS USED IN SOLUTION

1282   1 APR 1972   01:45:02.4  39.235N  20.729E                        79    IS ORIGINAL DATA SOURCE =  ISC
                                                                                   6 STATION RECORDINGS USED IN SOLUTION

1283  16 FEB 1973   15:54:05.7  39.062N  22.413E                        79    IS ORIGINAL DATA SOURCE =  ISC
                                                                                   9 STATION RECORDINGS USED IN SOLUTION
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CAT.     DATE        TIME(GMT)      LAT      LONG    SL INTEN  MAG SM   H  DIS Q S          L O C A T I O N     A N D     C O M M E N T S
NO.  DAY-MO-YEAR   HR-MIN-SEC                            (MM)          (KM)(KM)
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1284  24 JUN 1974  10:55:04.0  39.600N  21.700E                              79   IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  ATH
                                                                                       0 STATION RECORDINGS USED IN SOLUTION

1285  18 JUL 1974  03:31:08.1  39.557N  21.892E                              79   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        7 STATION RECORDINGS USED IN SOLUTION

1286  28 JUL 1974  03:21:35.5  38.407N  22.192E                              79   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       10 STATION RECORDINGS USED IN SOLUTION

1287  27 OCT 1974  13:09:51.4  39.142N  20.666E                              79   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        9 STATION RECORDINGS USED IN SOLUTION

1288   8 NOV 1974  10:28:41.9  38.420N  22.193E                              79   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        6 STATION RECORDINGS USED IN SOLUTION

1289   3 JAN 1957  07:36:27.0  38.200N  21.300E     IV     5.13              80   IS ORIGINAL DATA SOURCE =  BCIS
                                                                                     MAGNITUDE AUTHORITY =   ATH

1290  23 FEB 1960  07:47:51.0  38.860N  20.610E                              80   IS ORIGINAL DATA SOURCE =  ISS

1291  13 MAY 1965  21:09:16.7  39.220N  20.700E            4.50        58   80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       20 STATION RECORDINGS USED IN SOLUTION

1292   1 MAY 1967  07:09:03.0  39.600N  21.290E            5.50        34   80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      301 STATION RECORDINGS USED IN SOLUTION

1293  13 OCT 1967  16:06:50.0  38.500N  22.300E                              80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        6 STATION RECORDINGS USED IN SOLUTION

1294  15 DEC 1971  17:36:26.7  39.372N  20.829E                              80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        8 STATION RECORDINGS USED IN SOLUTION

1295   2 MAR 1972  07:09:27.9  38.234N  21.895E                              80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        4 STATION RECORDINGS USED IN SOLUTION

1296  11 JAN 1974  08:36:08.9  39.541N  21.097E                              80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        8 STATION RECORDINGS USED IN SOLUTION

1297  22 APR 1974  17:58:35.5  38.408N  22.200E            4.00        42   80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       39 STATION RECORDINGS USED IN SOLUTION

1298   9 JUN 1974  10:17:00.4  38.251N  21.919E                         4   80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        8 STATION RECORDINGS USED IN SOLUTION

1299  26 JUN 1974  22:56:37.0  39.608N  21.674E                              80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       10 STATION RECORDINGS USED IN SOLUTION

1300  15 OCT 1974  18:17:42.0  39.552N  21.144E                              80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        7 STATION RECORDINGS USED IN SOLUTION
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CAT.      DATE      TIME(GMT)     LAT      LONG    SL INTEN  MAG SM   H  DIS Q S        L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR  HR-MIN-SEC                         (MM)           (KM)(KM)
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1301  12 NOV 1974  00:26:06.8  38.743N  20.632E                             80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       7 STATION RECORDINGS USED IN SOLUTION

1302  31 MAY 1975  06:00:18.6  39.430N  20.910E                             80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       7 STATION RECORDINGS USED IN SOLUTION

1303  15 SEP 1975  06:08:23.9  38.265N  21.964F                             80   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       8 STATION RECORDINGS USED IN SOLUTION

1304  11 MAR 1938  14:50:55.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1305  13 MAR 1938  17:45:32.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1306  22 JUL 1943  07:09:28.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1307   8 JAN 1945  22:42:12.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1308  21 NOV 1946  01:43:28.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1309  21 APR 1948  23:42:42.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1310  22 APR 1948  10:42:45.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1311  30 JUN 1948  12:21:13.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1312  26 JUN 1949  05:42:20.0  38.800N  20.600E                             81   IS ORIGINAL DATA SOURCE =  ISS

1313   9 JAN 1951  00:27:58.0  38.800N  20.600F      IV                     81   IS ORIGINAL DATA SOURCE =  ISS

1314  16 JAN 1951  12:36:09.0  38.800N  20.600E      IV                     81   IS ORIGINAL DATA SOURCE =  ISS

1315  14 SEP 1953  14:56:10.0  38.300N  21.000E      VII     5.75           81   IS ORIGINAL DATA SOURCE =  BCIS
                                                                                    MAGNITUDE AUTHORITY =    ATH

1316  14 SEP 1953  16:13:54.0  38.300N  21.000E                             81   IS QUALITY =    REPT
                                                                                    ORIGINAL DATA SOURCE =  BCIS

1317  15 SEP 1953  11:34:26.0  38.500N  20.750E      IV                     81   IS ISC EFFECTS CODE = FELT
                                                                                    QUALITY =    REPT
                                                                                    ORIGINAL DATA SOURCE =  BCIS

1318  15 SEP 1953  11:37:57.0  38.500N  20.750E      IV      5.38           81   IS ISC EFFECTS CODE = FELT
                                                                                    QUALITY =    REPT
                                                                                    ORIGINAL DATA SOURCE =  BCIS
                                                                                    MAGNITUDE AUTHORITY =    ATH

1319   9 OCT 1953  17:31:32.0  38.300N  21.000E                             81   IS QUALITY =    FRSH
                                                                                    ORIGINAL DATA SOURCE =  BCIS

1320  10 OCT 1953  21:29:13.0  38.300N  21.000E      VI                     81   IS DATA OBTAINED VIA ISS
                                                                                    ORIGINAL DATA SOURCE =  STR
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CAT.     DATE      TIME(GMT)     LAT      LONG   SL INTEN   MAG SM  H DIS Q S       L O C A T I O N   A N D   C O M M E N T S
NO.   DAY-MO-YEAR  HR-MIN-SEC                        (MM)          (KM)(KM)
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1321  10 OCT 1953  21:29:13.0  38.300N  21.000E     VI      5.63       81  IS ORIGINAL DATA SOURCE =  BCIS
                                                                              MAGNITUDE AUTHORITY =   ATH

1322   8 NOV 1953  01:12:27.0  38.300N  21.000E     V                  81  IS ORIGINAL DATA SOURCE =  BCIS

1323  23 MAR 1957  19:32:30.0  38.800N  20.600E                        81  IS ORIGINAL DATA SOURCE =  BCIS

1324  17 JUN 1957  15:23:52.0  38.500N  20.750E                        81  IS ORIGINAL DATA SOURCE =  BCIS

1325  20 JUL 1960  09:18:54.0  38.400N  22.200E     VI                 81  IS ORIGINAL DATA SOURCE =  BCIS

1326  16 NOV 1960  04:28:42.0  39.500N  21.000E                        81  IS QUALITY =    APRX
                                                                              ORIGINAL DATA SOURCE =  BCIS

1327  19 JAN 1962  22:18:35.0  38.400N  22.200E     VI      5.63       81  IS DATA OBTAINED VIA BCIS
                                                                              ORIGINAL DATA SOURCE =  MOS
                                                                              MAGNITUDE AUTHORITY =   ATH

1328  27 JAN 1962  05:42:40.0  38.800N  20.600E                        81  IS ORIGINAL DATA SOURCE =  BCIS

1329   4 JUN 1963  22:11:35.0  38.900N  20.600E     VII     5.20       81  IS ORIGINAL DATA SOURCE =  BCIS
                                                                              MAGNITUDE AUTHORITY =   ATH

1330   7 JUL 1965  23:26:34.0  38.400N  22.200E             3.80       81  IS DATA OBTAINED VIA ISC
                                                                              ORIGINAL DATA SOURCE =  ATH
                                                                                 3 STATION RECORDINGS USED IN SOLUTION

1331  13 JUN 1966  11:44:52.0  39.500N  21.000E             4.00       81  IS DATA OBTAINED VIA ISC
                                                                              ORIGINAL DATA SOURCE =  ATH
                                                                                 5 STATION RECORDINGS USED IN SOLUTION

1332  11 JUL 1966  04:53:46.0  39.500N  21.000E                        81  IS DATA OBTAINED VIA ISC
                                                                              ORIGINAL DATA SOURCE =  ATH
                                                                                 3 STATION RECORDINGS USED IN SOLUTION

1333  26 AUG 1966  01:19:33.1  39.500N  21.000E                        81  IS DATA OBTAINED VIA ISC
                                                                              ORIGINAL DATA SOURCE =  ATH
                                                                                 3 STATION RECORDINGS USED IN SOLUTION

1334  17 JUL 1967  01:33:01.0  39.500N  21.000E                        81  IS DATA OBTAINED VIA ISC
                                                                              ORIGINAL DATA SOURCE =  ATH
                                                                                 2 STATION RECORDINGS USED IN SOLUTION

1335   6 NOV 1967  10:32:58.0  39.050N  20.610E             4.60    1  81  IS ORIGINAL DATA SOURCE =  ISC
                                                                                44 STATION RECORDINGS USED IN SOLUTION

1336  10 APR 1968  17:07:23.0  38.400N  22.200E                        81  IS ORIGINAL DATA SOURCE =  ISC
                                                                                 8 STATION RECORDINGS USED IN SOLUTION

1337  19 FEB 1969  20:17:44.0  38.500N  20.750E                        81  IS DATA OBTAINED VIA ISC
                                                                              ORIGINAL DATA SOURCE =  ATH
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CAT.      DATE        TIME(GMT)      LAT      LONG    SL INTEN  MAG SM   H  DIS Q S       L O C A T I O N   A N D   C O M M E N T S
NO.   DAY-MO-YEAR   HR-MIN-SEC                           (MM)          (KM)(KM)
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                                                                                   2 STATION RECORDINGS USED IN SOLUTION

1338  24 JUL 1969  00:41:24.4  38.210N  21.840E                     14   81   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  15 STATION RECORDINGS USED IN SOLUTION

1339  17 FEB 1970  04:53:32.0  39.500N  21.000E                          81   IS DATA OBTAINED VIA ISC
                                                                             ORIGINAL DATA SOURCE =  ATH
                                                                                   2 STATION RECORDINGS USED IN SOLUTION

1340  24 DEC 1970  04:43:05.0  38.290N  22.030E                          81   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   7 STATION RECORDINGS USED IN SOLUTION

1341   2 FEB 1973  06:59:47.8  38.580N  20.691E                          81   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   4 STATION RECORDINGS USED IN SOLUTION

1342   5 AUG 1974  04:36:13.0  38.400N  22.200E           2.80           81   IS DATA OBTAINED VIA ISC
                                                                             ORIGINAL DATA SOURCE =  ATH
                                                                                   0 STATION RECORDINGS USED IN SOLUTION

1343  11 JUL 1975  11:36:41.0  38.200N  21.800E           3.10           81   IS DATA OBTAINED VIA ISC
                                                                             ORIGINAL DATA SOURCE =  ATH
                                                                                   0 STATION RECORDINGS USED IN SOLUTION

1344  26 JUL 1975  03:23:10.7  38.215N  21.465E                          81   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   9 STATION RECORDINGS USED IN SOLUTION

1345  30 NOV 1975  07:07:44.1  39.486N  22.083E                          81   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  14 STATION RECORDINGS USED IN SOLUTION

1346   2 DEC 1975  13:57:31.0  38.266N  22.001E                          81   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   8 STATION RECORDINGS USED IN SOLUTION

1347  28 FEB 1968  04:36:19.3  38.320N  22.120E                          82   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   5 STATION RECORDINGS USED IN SOLUTION

1348   2 OCT 1969  23:13:40.6  38.470N  22.290E           4.70      45   82   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  50 STATION RECORDINGS USED IN SOLUTION

1349   8 MAR 1972  08:21:36.3  38.176N  21.703E                     33   82   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  20 STATION RECORDINGS USED IN SOLUTION

1350   4 JUL 1972  20:44:47.6  39.298N  20.727E                          82   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   4 STATION RECORDINGS USED IN SOLUTION

1351  18 DEC 1972  05:46:10.4  38.569N  22.377E                          82   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   4 STATION RECORDINGS USED IN SOLUTION

1352  25 JUN 1974  02:23:15.6  38.629N  20.652E                          82   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  10 STATION RECORDINGS USED IN SOLUTION

1353  11 JUL 1974  00:43:21.8  38.213N  21.880E                          82   IS ORIGINAL DATA SOURCE =  ISC
                                                                                   9 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1354 | 11 DEC 1974 | 17:39:56.0 | 38.538N | 22.348E | | | | | 9 | 82 | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1355 | 21 APR 1975 | 10:03:50.9 | 38.273N | 22.023E | | | | | | 82 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1356 | 20 JUL 1975 | 15:53:19.4 | 38.167N | 21.680E | | | | | 3 | 82 | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1357 | 4 MAR 1953 | 15:30:36.0 | 38.250N | 22.000E | | VII | | | | 83 | IS | ISC EFFECTS CODE = FELT<br>ORIGINAL DATA SOURCE = BCIS |
| 1358 | 8 JAN 1955 | 07:52:58.0 | 39.500N | 22.100E | | VII | 5.25 | | | 83 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = ATH |
| 1359 | 26 MAY 1959 | 18:01:11.0 | 38.300N | 22.100E | | V | | | | 83 | IS | ORIGINAL DATA SOURCE = BCIS |
| 1360 | 5 NOV 1960 | 20:20:48.0 | 39.090N | 20.600E | | | | | | 83 | IS | ORIGINAL DATA SOURCE = ISS |
| 1361 | 17 MAR 1963 | 14:17:23.0 | 39.400N | 20.820E | | | | | 56 | 83 | IS | ORIGINAL DATA SOURCE = ISS |
| 1362 | 24 MAY 1966 | 07:33:54.4 | 39.280N | 20.700E | | | | | | 83 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1363 | 9 AUG 1966 | 22:00:27.1 | 39.600N | 21.200E | | | | | | 83 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1364 | 30 AUG 1967 | 11:57:58.0 | 39.600N | 21.200E | | | 3.60 | | | 83 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>5 STATION RECORDINGS USED IN SOLUTION |
| 1365 | 22 MAY 1969 | 18:42:25.4 | 38.170N | 21.760E | | | | | | 83 | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1366 | 30 JUN 1970 | 22:15:13.8 | 38.820N | 20.580E | | | 4.20 | | | 83 | IS | ORIGINAL DATA SOURCE = ISC<br>38 STATION RECORDINGS USED IN SOLUTION |
| 1367 | 11 JUL 1970 | 23:29:19.6 | 38.860N | 20.570E | | | 4.50 | | 36 | 83 | IS | ORIGINAL DATA SOURCE = ISC<br>76 STATION RECORDINGS USED IN SOLUTION |
| 1368 | 1 SEP 1972 | 09:37:01.5 | 38.868N | 20.576E | | | | | | 83 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1369 | 31 OCT 1972 | 11:30:54.2 | 38.312N | 22.120E | | | 4.00 | | 64 | 83 | IS | ORIGINAL DATA SOURCE = ISC<br>22 STATION RECORDINGS USED IN SOLUTION |
| 1370 | 1 SEP 1973 | 15:20:02.1 | 38.691N | 22.451E | | | | | | 83 | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |

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CAT.     DATE       TIME(GMT)        LAT      LONG     SL INTEN  MAG SM  H  DIS Q S        L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                               (MM)          (KM)(KM)
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1371  15 FEB 1974  13:14:05.9  38.201N  21.855E                        10  83  IS ORIGINAL DATA SOURCE =  ISC
                                                                                   19 STATION RECORDINGS USED IN SOLUTION

1372  26 JUL 1975  17:04:57.7  38.224N  21.929E                            83  IS ORIGINAL DATA SOURCE =  ISC
                                                                                   14 STATION RECORDINGS USED IN SOLUTION

1373  20 NOV 1953  19:13:57.0  38.400N  20.800E      V       5.37          84  IS ORIGINAL DATA SOURCE =  BCIS
                                                                                  MAGNITUDE AUTHORITY =   ATH

1374  25 JUN 1956  10:50:53.0  38.400N  20.800E                            84  IS ORIGINAL DATA SOURCE =  BCIS

1375   8 OCT 1957  07:00:47.0  38.920N  20.560E                            84  IS ORIGINAL DATA SOURCE =  ISS

1376  23 FEB 1960  00:30:59.0  39.030N  20.580E                            84  IS ORIGINAL DATA SOURCE =  ISS

1377  23 FEB 1960  07:34:31.0  38.990N  20.570E                            84  IS ORIGINAL DATA SOURCE =  ISS

1378  12 APR 1966  19:14:38.2  39.400N  20.800E                        50  84  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                    4 STATION RECORDINGS USED IN SOLUTION

1379   4 MAY 1967  13:31:07.8  39.630N  21.260E              4.70      39  84  IS ORIGINAL DATA SOURCE =  ISC
                                                                                   72 STATION RECORDINGS USED IN SOLUTION

1380   8 JUL 1967  05:42:48.0  39.400N  20.800E                            84  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                    3 STATION RECORDINGS USED IN SOLUTION

1381  23 JUL 1967  09:17:58.0  39.400N  20.800E              3.30          84  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                    4 STATION RECORDINGS USED IN SOLUTION

1382  27 AUG 1967  06:58:45.0  39.400N  20.800E              3.50          84  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                    5 STATION RECORDINGS USED IN SOLUTION

1383   2 DEC 1967  05:33:22.0  39.100N  20.600E              3.80          84  IS DATA OBTAINED VIA ISC
                                                                                  ORIGINAL DATA SOURCE =  ATH
                                                                                    3 STATION RECORDINGS USED IN SOLUTION

1384  28 SEP 1969  00:41:22.6  38.240N  21.990E                            84  IS ORIGINAL DATA SOURCE =  ISC
                                                                                    8 STATION RECORDINGS USED IN SOLUTION

1385  30 JUN 1970  18:21:22.0  38.800N  20.570E              4.60      22  84  IS ORIGINAL DATA SOURCE =  ISC
                                                                                   89 STATION RECORDINGS USED IN SOLUTION

1386   2 JUL 1970  07:50:14.0  38.720N  20.590E              4.90      27  84  IS ORIGINAL DATA SOURCE =  ISC
                                                                                  109 STATION RECORDINGS USED IN SOLUTION

1387   7 JUN 1971  08:25:53.9  38.369N  22.221E                            84  IS ORIGINAL DATA SOURCE =  ISC
                                                                                    4 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q | S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1388 | 15 JUN 1972 | 15:26:02.2 | 38.254N | 22.038E | | | | | | 84 | | IS | ORIGINAL DATA SOURCE = ISC<br>9 STATION RECORDINGS USED IN SOLUTION |
| 1389 | 6 JUL 1972 | 19:37:12.5 | 38.420N | 22.279E | | | | | | 84 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1390 | 9 OCT 1972 | 03:29:21.8 | 38.149N | 21.660E | | | | | | 84 | | IS | ORIGINAL DATA SOURCE = ISC<br>12 STATION RECORDINGS USED IN SOLUTION |
| 1391 | 1 JUL 1973 | 05:54:39.1 | 38.226N | 21.956E | | | | | | 84 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1392 | 3 JUL 1973 | 11:54:19.0 | 39.103N | 20.600E | | | 3.10 | | | 84 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>0 STATION RECORDINGS USED IN SOLUTION |
| 1393 | 19 OCT 1973 | 09:10:59.7 | 39.511N | 20.961E | | | | | | 84 | | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 1394 | 7 DEC 1973 | 11:24:50.1 | 38.157N | 21.710E | | | | | | 84 | | IS | ORIGINAL DATA SOURCE = ISC<br>8 STATION RECORDINGS USED IN SOLUTION |
| 1395 | 18 APR 1974 | 10:05:17.9 | 38.214N | 21.925E | | | | | | 84 | | IS | ORIGINAL DATA SOURCE = ISC<br>4 STATION RECORDINGS USED IN SOLUTION |
| 1396 | 12 MAR 1975 | 12:02:44.5 | 39.590N | 21.920E | | | | | | 84 | | IS | ORIGINAL DATA SOURCE = ISC<br>7 STATION RECORDINGS USED IN SOLUTION |
| 1397 | 5 OCT 1949 | 16:20:35.0 | 39.000N | 22.500E | | | | | | 85 | | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |
| 1398 | 13 JUL 1952 | 07:09:42.0 | 39.000N | 22.500E | | VI | | | | 85 | | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 1399 | 13 JUL 1952 | 07:09:46.0 | 39.000N | 22.500E | | VI | | | | 85 | | IS | DATA OBTAINED VIA ISS<br>ORIGINAL DATA SOURCE = ATH |
| 1400 | 14 SEP 1953 | 14:56:14.0 | 38.500N | 20.700E | | VII | | | | 85 | | IS | DATA OBTAINED VIA ISS<br>ORIGINAL DATA SOURCE = STR |
| 1401 | 8 JAN 1955 | 07:52:57.0 | 39.000N | 22.500E | | | | | | 85 | | IS | DATA OBTAINED VIA USE<br>REPORTED FELT INFORMATION<br>ORIGINAL DATA SOURCE = CGS |
| 1402 | 22 FEB 1960 | 21:04:14.0 | 38.930N | 20.550E | | | | | | 85 | | IS | ORIGINAL DATA SOURCE = ISS |
| 1403 | 16 SEP 1966 | 21:00:00.7 | 39.000N | 22.500E | | | | | | 85 | | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = ATH<br>4 STATION RECORDINGS USED IN SOLUTION |

EARTHQUAKE CATALOG, PORTO COLOMBIA RESERVOIR

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CAT.     DATE       TIME(GMT)      LAT       LONG    SL INTEN  MAG SM  H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                             (MM)          (KM)(KM)
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1     16 JAN 1963  16:28:42.0  19.000S  49.000W            4.10          141   IS DATA OBTAINED VIA ISC
                                                                                   ORIGINAL DATA SOURCE =  LAO
                                                                                     1 STATION RECORDINGS USED IN SOLUTION
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                                          CHRONOLOGICAL CATALOG, ALMENDRA (TORMES) RESERVOIR
CAT.     DATE        TIME(GMT)      LAT       LONG    SL INTEN  MAG SM   H  DIS Q S        L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR  HR-MIN-SEC                             (MM)             (KM)(KM)
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1     10 FEB 1961  18:51:55.0  41.300N    6.300W    VI                      34   IS ORIGINAL DATA SOURCE =  BCIS

2     10 FEB 1961  19:16:28.0  41.500N    6.300W                            34   IS QUALITY =    REPT
                                                                                    ORIGINAL DATA SOURCE =  BCIS

3     10 FEB 1961  20:02:54.0  41.500N    6.300W                            34   IS QUALITY =    REPT
                                                                                    ORIGINAL DATA SOURCE =  BCIS

4     22 DEC 1961  12:00:45.0  42.000N    6.000W                            89   IS QUALITY =    APRX
                                                                                    ORIGINAL DATA SOURCE =  BCIS

5      1 NOV 1967  01:45:17.0  42.200N    7.250W                           143   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  MDD
                                                                                      3 STATION RECORDINGS USED IN SOLUTION

6      1 NOV 1967  02:00:20.0  42.200N    7.250W             4.00          143   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  MDD
                                                                                      3 STATION RECORDINGS USED IN SOLUTION

7      3 MAY 1973  20:55:41.8  41.114N    7.008W                       33   72   IS ORIGINAL DATA SOURCE =  ISC
                                                                                      6 STATION RECORDINGS USED IN SOLUTION

8     25 JAN 1975  13:47:12.0  42.500N    7.000W                           159   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  LIS
                                                                                      0 STATION RECORDINGS USED IN SOLUTION

9     17 APR 1975  14:49:20.0  41.700N    7.300W                           110   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  LIS
                                                                                      0 STATION RECORDINGS USED IN SOLUTION

10     4 JUL 1975  15:21:47.0  41.200N    7.400W                           104   IS DATA OBTAINED VIA ISC
                                                                                    ORIGINAL DATA SOURCE =  LIS
                                                                                      0 STATION RECORDINGS USED IN SOLUTION
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                                     DISTANCE CATALOG, ALMENDRA (TORMES) RESERVOIR

CAT.     DATE        TIME(GMT)      LAT        LONG    SL INTEN  MAG SM  H  DIS Q S         L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR  HR-MIN-SEC                             (MM)          (KM)(KM)
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1      10 FEB 1961  18:51:55.0  41.500N    6.300W      VI                    34   IS ORIGINAL DATA SOURCE =  BCIS
2      10 FEB 1961  19:16:28.0  41.500N    6.300W                            34   IS QUALITY =    REPT
                                                                                     ORIGINAL DATA SOURCE =  BCIS
3      10 FEB 1961  20:02:54.0  41.500N    6.300W                            34   IS QUALITY =    REPT
                                                                                     ORIGINAL DATA SOURCE =  BCIS
4       3 MAY 1973  20:55:41.8  41.114N    7.008W                        33  72   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       6 STATION RECORDINGS USED IN SOLUTION
5      22 DEC 1961  12:00:45.0  42.000N    6.000W                            89   IS QUALITY =    APRX
                                                                                     ORIGINAL DATA SOURCE =  BCIS
6       4 JUL 1975  15:21:47.0  41.200N    7.400W                           104   IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  LIS
                                                                                       0 STATION RECORDINGS USED IN SOLUTION
7      17 APR 1975  14:49:20.0  41.700N    7.300W                           110   IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  LIS
                                                                                       0 STATION RECORDINGS USED IN SOLUTION
8       1 NOV 1967  01:45:17.0  42.200N    7.250W                           143   IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  MDD
                                                                                       3 STATION RECORDINGS USED IN SOLUTION
9       1 NOV 1967  02:00:20.0  42.200N    7.250W            4.00           143   IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  MDD
                                                                                       3 STATION RECORDINGS USED IN SOLUTION
10     25 JAN 1975  13:47:12.0  42.500N    7.000W                           159   IS DATA OBTAINED VIA ISC
                                                                                     ORIGINAL DATA SOURCE =  LIS
                                                                                       0 STATION RECORDINGS USED IN SOLUTION
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CHRONOLOGICAL CATALOG, SEFID RUD RESERVOIR

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CAT.     DATE       TIME(GMT)      LAT       LONG    SL INTEN  MAG SM   H  DIS Q S         L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR   HR-MIN-SEC                          (MM)            (KM)(KM)
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1      9 NOV 1944  19:39:40.0  38.000N  48.400E                              164    IS ORIGINAL DATA SOURCE =  ISS
2     17 JUN 1948  14:09:22.0  36.500N  49.000E                               40    IS ORIGINAL DATA SOURCE =  ISS
3     30 JUN 1948  19:31:39.0  36.500N  49.000E                               40    IS ORIGINAL DATA SOURCE =  ISS
4      5 JUN 1951  03:34:49.0  36.000N  48.500E                              111    IS ORIGINAL DATA SOURCE =  ISS
5     18 JUL 1952  00:43:51.0  37.500N  50.100E                              108    IS ORIGINAL DATA SOURCE =  ISS
6     12 APR 1956  22:34:44.0  37.000N  50.000E                               65    IS DATA OBTAINED VIA USE
                                                                                       ORIGINAL DATA SOURCE =  CGS
7     12 APR 1956  22:34:46.0  37.300N  50.200E                               99    IS ORIGINAL DATA SOURCE =  ISS
8     12 APR 1956  22:34:48.0  37.250N  50.250E             5.50              99    IS ORIGINAL DATA SOURCE =  BCIS
                                                                                       MAGNITUDE AUTHORITY =   MOS
9     12 APR 1956  22:34:52.0  38.000N  50.000E             5.50             152    IS DATA OBTAINED VIA BCIS
                                                                                       ORIGINAL DATA SOURCE =  MOS
                                                                                       MAGNITUDE AUTHORITY =   MOS
10     6 MAY 1957  15:06:47.0  36.000N  51.000E                              169    IS DATA OBTAINED VIA USE
                                                                                       ORIGINAL DATA SOURCE =  CGS
11     6 MAY 1957  15:06:47.0  36.000N  51.000E                              169    IS ORIGINAL DATA SOURCE =  BCIS
12    19 AUG 1957  07:22:27.0  38.000N  49.000E                              144    IS ORIGINAL DATA SOURCE =  BCIS
13    19 AUG 1957  07:22:27.0  38.000N  49.000E                              144    IS DATA OBTAINED VIA BCIS
                                                                                       ORIGINAL DATA SOURCE =  MOS
14    21 SEP 1958  16:18:30.0  36.000N  49.000E                               87    IS DATA OBTAINED VIA USE
                                                                                       ORIGINAL DATA SOURCE =  CGS
15    31 MAY 1959  13:01:44.0  37.700N  48.990E                              112    IS ORIGINAL DATA SOURCE =  ISS
16    31 MAY 1959  13:01:44.0  37.500N  49.000E                               91    IS DATA OBTAINED VIA USE
                                                                                       ORIGINAL DATA SOURCE =  CGS
17    31 MAY 1959  13:01:44.0  37.500N  49.000E                               91    IS ORIGINAL DATA SOURCE =  BCIS
18    31 MAY 1959  13:01:52.0  37.500N  49.000E                               91    IS DATA OBTAINED VIA BCIS
                                                                                       ORIGINAL DATA SOURCE =  MOS
19    31 MAY 1959  13:07:48.0  37.500N  49.000E                               91    IS QUALITY =    REPT
                                                                                       ORIGINAL DATA SOURCE =  BCIS
20     2 APR 1960  22:36:09.0  36.000N  50.000E                              100    IS DATA OBTAINED VIA BCIS
                                                                                       ORIGINAL DATA SOURCE =  MOS
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 23 JUN 1960 | 03:37:42.0 | 37.000N | 49.500E | | | | | | 33 | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 22 | 1 SEP 1962 | 19:20:22.0 | 35.750N | 48.000E | | IX | 7.75 | | | 163 | IS | ISC EFFECTS CODE = 010100<br>DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = QUE<br>MAGNITUDE AUTHORITY = BRK |
| 23 | 1 SEP 1962 | 19:20:30.0 | 36.000N | 49.000E | | IX | 7.50 | | | 87 | IS | ISC EFFECTS CODE = 010100<br>DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = SHL<br>MAGNITUDE AUTHORITY = SHL |
| 24 | 1 SEP 1962 | 19:20:39.9 | 35.500N | 49.900E | | IX | 7.25 | | 27 | 135 | IS | ISC EFFECTS CODE = 010100<br>ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = PAS |
| 25 | 1 SEP 1962 | 19:20:40.0 | 35.580N | 49.880E | | | | | 29 | 136 | IS | ORIGINAL DATA SOURCE = ISS |
| 26 | 1 SEP 1962 | 20:27:36.0 | 35.300N | 49.600E | | | 4.50 | | | 160 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = STR |
| 27 | 1 SEP 1962 | 20:27:37.0 | 35.600N | 49.900E | | | 4.50 | | | 135 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = STR |
| 28 | 2 SEP 1962 | 07:12:02.0 | 35.600N | 49.200E | | | 4.88 | | | 126 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = MOS |
| 29 | 2 SEP 1962 | 07:12:03.0 | 35.700N | 49.400E | | | 4.88 | | | 114 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = MOS |
| 30 | 2 SEP 1962 | 13:21:18.0 | 38.000N | 48.500E | | | 4.00 | | | 160 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = MOS |
| 31 | 3 SEP 1962 | 02:08:26.0 | 35.750N | 50.000E | | | | | | 123 | IS | ORIGINAL DATA SOURCE = BCIS |
| 32 | 4 SEP 1962 | 13:30:12.0 | 36.600N | 49.900E | | | 5.60 | | | 51 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = UPP |
| 33 | 4 SEP 1962 | 13:30:14.0 | 35.590N | 49.740E | | | | | 43 | 131 | IS | ORIGINAL DATA SOURCE = ISS |
| 34 | 6 SEP 1962 | 17:04:25.0 | 36.300N | 49.500E | | | 3.75 | | | 50 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = MOS |
| 35 | 12 SEP 1962 | 02:16:42.0 | 35.600N | 49.900E | | | | | | 135 | IS | QUALITY = REPT<br>ORIGINAL DATA SOURCE = BCIS |

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CAT.      DATE        TIME(GMT)       LAT       LONG     SL INTEN  MAG SM   H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.   DAY-MO-YEAR   HR-MIN-SEC                               (MM)          (KM)(KM)
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36     13 OCT 1962  10:23:30.0  36.000N  49.500E             5.25            82   IS DATA OBTAINED VIA BCIS
                                                                                     REPORTED FELT INFORMATION
                                                                                     ORIGINAL DATA SOURCE =  PEK
                                                                                     MAGNITUDE AUTHORITY =   KEW

37     13 OCT 1962  10:23:30.0  36.800N  49.700E             5.50            32   IS DATA OBTAINED VIA BCIS
                                                                                     REPORTED FELT INFORMATION
                                                                                     ORIGINAL DATA SOURCE =  SHL
                                                                                     MAGNITUDE AUTHORITY =   TUL

38     13 OCT 1962  10:23:32.0  36.000N  49.500E             5.20            82   IS DATA OBTAINED VIA BCIS
                                                                                     REPORTED FELT INFORMATION
                                                                                     ORIGINAL DATA SOURCE =  EBM
                                                                                     MAGNITUDE AUTHORITY =   LWI

39     13 OCT 1962  10:23:37.0  35.900N  50.300E             5.70           134   IS REPORTED FELT INFORMATION
                                                                                     ORIGINAL DATA SOURCE =  BCIS
                                                                                     MAGNITUDE AUTHORITY =   UPP

40     13 OCT 1962  10:23:38.0  35.750N  50.070E                      35 127   IS ORIGINAL DATA SOURCE =  ISS

41     13 OCT 1962  10:23:40.0  36.000N  50.000E             5.50           100   IS DATA OBTAINED VIA BCIS
                                                                                     REPORTED FELT INFORMATION
                                                                                     ORIGINAL DATA SOURCE =  MOS
                                                                                     MAGNITUDE AUTHORITY =   MOS

42      2 DEC 1962  22:12:14.0  35.700N  50.000E     III                    128   IS ORIGINAL DATA SOURCE =  BCIS

43      2 DEC 1962  22:21:28.0  35.700N  50.000E     III     5.00           128   IS ORIGINAL DATA SOURCE =  BCIS
                                                                                     MAGNITUDE AUTHORITY =   MOS

44      2 DEC 1962  23:36:35.0  35.700N  50.000E     V                      128   IS ORIGINAL DATA SOURCE =  BCIS

45     27 JAN 1963  19:35:20.0  37.000N  48.400E             5.30            90   IS DATA OBTAINED VIA BCIS
                                                                                     ORIGINAL DATA SOURCE =  SHL
                                                                                     MAGNITUDE AUTHORITY =   QUE

46     24 MAR 1963  12:43:58.0  37.000N  48.000E             5.70           124   IS DATA OBTAINED VIA BCIS
                                                                                     ORIGINAL DATA SOURCE =  SHL
                                                                                     MAGNITUDE AUTHORITY =   LJU

47     28 MAY 1963  10:32:50.0  35.700N  49.600E             4.30           116   IS ORIGINAL DATA SOURCE =  BCIS
                                                                                     MAGNITUDE AUTHORITY =   COL

48      8 FEB 1964  06:28:27.5  37.100N  51.040E             4.60         40 156   IS ORIGINAL DATA SOURCE =  ISC
                                                                                       37 STATION RECORDINGS USED IN SOLUTION

49     15 MAY 1964  01:56:08.0  35.760N  49.860E                          29 117   IS ORIGINAL DATA SOURCE =  ISC
                                                                                        8 STATION RECORDINGS USED IN SOLUTION
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 3 NOV 1954 | 17:36:08.5 | 35.630N | 50.290E | | | 5.10 | | 42 | 148 | IS | ORIGINAL DATA SOURCE = ISC<br>59 STATION RECORDINGS USED IN SOLUTION |
| 51 | 29 OCT 1955 | 15:59:42.1 | 37.900N | 48.700E | | | 4.60 | | 33 | 142 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = USCGS<br>11 STATION RECORDINGS USED IN SOLUTION |
| 52 | 8 NOV 1955 | 03:14:12.8 | 36.100N | 50.740E | | | 4.80 | | 41 | 143 | IS | ORIGINAL DATA SOURCE = ISC<br>55 STATION RECORDINGS USED IN SOLUTION |
| 53 | 23 JUN 1967 | 13:15:08.0 | 35.500N | 49.600E | | | | | 38 | 138 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 54 | 25 AUG 1967 | 12:26:50.5 | 35.580N | 49.330E | | | 4.70 | | 55 | 128 | IS | ORIGINAL DATA SOURCE = ISC<br>49 STATION RECORDINGS USED IN SOLUTION |
| 55 | 4 JUN 1968 | 01:44:25.6 | 37.500N | 49.190E | | | 4.60 | | 49 | 87 | IS | ORIGINAL DATA SOURCE = ISC<br>51 STATION RECORDINGS USED IN SOLUTION |
| 56 | 2 AUG 1968 | 03:59:27.1 | 36.850N | 49.330E | | | 4.70 | | 36 | 13 | IS | ORIGINAL DATA SOURCE = ISC<br>44 STATION RECORDINGS USED IN SOLUTION |
| 57 | 19 JAN 1970 | 17:19:29.2 | 37.010N | 48.980E | | | 4.50 | | 47 | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>36 STATION RECORDINGS USED IN SOLUTION |
| 58 | 11 JUL 1970 | 22:41:13.5 | 37.570N | 49.070E | | | 5.20 | | 47 | 96 | IS | ORIGINAL DATA SOURCE = ISC<br>162 STATION RECORDINGS USED IN SOLUTION |
| 59 | 15 MAY 1971 | 04:53:07.1 | 37.957N | 49.044E | | | 4.70 | | 50 | 139 | IS | ORIGINAL DATA SOURCE = ISC<br>44 STATION RECORDINGS USED IN SOLUTION |
| 60 | 18 JAN 1972 | 21:12:02.5 | 37.600N | 48.814E | | | 4.80 | | 33 | 108 | IS | ORIGINAL DATA SOURCE = ISC<br>95 STATION RECORDINGS USED IN SOLUTION |
| 61 | 30 OCT 1973 | 15:59:30.8 | 36.946N | 50.706E | | | 4.10 | | 48 | 123 | IS | ORIGINAL DATA SOURCE = ISC<br>42 STATION RECORDINGS USED IN SOLUTION |
| 62 | 30 OCT 1973 | 16:38:52.8 | 37.011N | 50.610E | | | | | 19 | 117 | IS | ORIGINAL DATA SOURCE = ISC<br>23 STATION RECORDINGS USED IN SOLUTION |
| 63 | 13 MAR 1975 | 17:33:12.7 | 37.082N | 50.698E | | | 4.40 | | 27 | 126 | IS | ORIGINAL DATA SOURCE = ISC<br>37 STATION RECORDINGS USED IN SOLUTION |
| 64 | 11 APR 1975 | 14:26:46.4 | 35.649N | 50.354E | | | 4.70 | | 59 | 150 | IS | ORIGINAL DATA SOURCE = ISC<br>58 STATION RECORDINGS USED IN SOLUTION |

## DISTANCE CATALOG, SEFID RUD RESERVOIR

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 AUG 1968 | 03:59:27.1 | 36.850N | 49.330E | | | 4.70 | | 36 | 13 | IS | ORIGINAL DATA SOURCE = ISC<br>44 STATION RECORDINGS USED IN SOLUTION |
| 2 | 13 OCT 1962 | 10:23:30.0 | 36.800N | 49.700E | | | 5.50 | | | 32 | IS | DATA OBTAINED VIA BCIS<br>REPORTED FELT INFORMATION<br>ORIGINAL DATA SOURCE = SHL<br>MAGNITUDE AUTHORITY = TJL |
| 3 | 23 JUN 1960 | 03:37:42.0 | 37.000N | 49.500E | | | | | | 33 | IS | QUALITY = APRX<br>ORIGINAL DATA SOURCE = BCIS |
| 4 | 17 JUN 1949 | 14:08:22.0 | 36.500N | 49.000E | | | | | | 40 | IS | ORIGINAL DATA SOURCE = ISS |
| 5 | 30 JUN 1948 | 19:31:39.0 | 36.500N | 49.000E | | | | | | 40 | IS | ORIGINAL DATA SOURCE = ISS |
| 6 | 19 JAN 1970 | 17:19:29.2 | 37.010N | 48.990E | | | 4.50 | | 47 | 45 | IS | ORIGINAL DATA SOURCE = ISC<br>36 STATION RECORDINGS USED IN SOLUTION |
| 7 | 6 SEP 1962 | 17:04:25.0 | 36.300N | 49.500E | | | 3.75 | | | 50 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = MOS |
| 8 | 4 SEP 1962 | 13:30:12.0 | 36.600N | 49.900E | | | 5.60 | | | 51 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = UPP |
| 9 | 12 APR 1956 | 22:34:44.0 | 37.000N | 50.000E | | | | | | 65 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |
| 10 | 13 OCT 1962 | 10:23:30.0 | 36.000N | 49.500E | | | 5.25 | | | 82 | IS | DATA OBTAINED VIA BCIS<br>REPORTED FELT INFORMATION<br>ORIGINAL DATA SOURCE = PEK<br>MAGNITUDE AUTHORITY = KEW |
| 11 | 13 OCT 1962 | 10:23:32.0 | 36.000N | 49.500E | | | 5.20 | | | 82 | IS | DATA OBTAINED VIA BCIS<br>REPORTED FELT INFORMATION<br>ORIGINAL DATA SOURCE = EBM<br>MAGNITUDE AUTHORITY = LWI |
| 12 | 21 SEP 1958 | 16:18:30.0 | 36.000N | 49.000E | | | | | | 87 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |
| 13 | 1 SEP 1962 | 19:20:30.0 | 36.000N | 49.000E | | IX | 7.50 | | | 87 | IS | ISC EFFECTS CODE = 010100<br>DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = SHL<br>MAGNITUDE AUTHORITY = SHL |
| 14 | 4 JUN 1968 | 01:44:25.6 | 37.500N | 49.190E | | | 4.50 | | 49 | 87 | IS | ORIGINAL DATA SOURCE = ISC<br>51 STATION RECORDINGS USED IN SOLUTION |
| 15 | 27 JAN 1963 | 19:35:20.0 | 37.000N | 48.400E | | | 5.30 | | | 90 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = SHL |

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CAT.     DATE        TIME(GMT)      LAT      LONG    SL INTEN  MAG SM  H  DIS Q S          L O C A T I O N    A N D    C O M M E N T S
NO.  DAY-MO-YEAR   HR-MIN-SEC                           (MM)         (KM)(KM)
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                                                                                  MAGNITUDE AUTHORITY =   QUE

16    31 MAY 1959  13:01:44.0  37.500N  49.000E                             91   IS ORIGINAL DATA SOURCE =  BCIS

17    31 MAY 1959  13:01:44.0  37.500N  49.000E                             91   IS DATA OBTAINED VIA USE
                                                                                  ORIGINAL DATA SOURCE =  CGS

18    31 MAY 1959  13:01:52.0  37.500N  49.000E                             91   IS DATA OBTAINED VIA BCIS
                                                                                  ORIGINAL DATA SOURCE =  MOS

19    31 MAY 1959  13:07:48.0  37.500N  49.000E                             91   IS QUALITY =    REPT
                                                                                  ORIGINAL DATA SOURCE =  BCIS

20    11 JUL 1970  22:41:13.5  37.570N  49.070E            5.20      47    96   IS ORIGINAL DATA SOURCE =  ISC
                                                                                  152 STATION RECORDINGS USED IN SOLUTION

21    12 APR 1956  22:34:46.0  37.300N  50.200E                             99   IS ORIGINAL DATA SOURCE =  ISS

22    12 APR 1956  22:34:48.0  37.250N  50.250E            5.50             99   IS ORIGINAL DATA SOURCE =  BCIS
                                                                                  MAGNITUDE AUTHORITY =   MOS

23     2 APR 1960  22:36:09.0  36.000N  50.000E                            100   IS DATA OBTAINED VIA BCIS
                                                                                  ORIGINAL DATA SOURCE =  MOS

24    13 OCT 1962  10:23:40.0  36.000N  50.000E            5.50            100   IS DATA OBTAINED VIA BCIS
                                                                                  REPORTED FELT INFORMATION
                                                                                  ORIGINAL DATA SOURCE =  MOS
                                                                                  MAGNITUDE AUTHORITY =   MOS

25    18 JUL 1952  00:43:51.0  37.500N  50.100E                            108   IS ORIGINAL DATA SOURCE =  ISS

26    18 JAN 1972  21:12:02.5  37.600N  48.814E            4.80      33   108   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    95 STATION RECORDINGS USED IN SOLUTION

27     5 JUN 1951  03:34:49.0  36.000N  48.500E                            111   IS ORIGINAL DATA SOURCE =  ISS

28    31 MAY 1959  13:01:44.0  37.700N  48.990E                            112   IS ORIGINAL DATA SOURCE =  ISS

29     2 SEP 1962  07:12:03.0  35.700N  49.400E            4.88            114   IS ORIGINAL DATA SOURCE =  BCIS
                                                                                  MAGNITUDE AUTHORITY =   MOS

30    28 MAY 1963  10:32:50.0  35.700N  49.600E            4.30            116   IS ORIGINAL DATA SOURCE =  BCIS
                                                                                  MAGNITUDE AUTHORITY =   COL

31    15 MAY 1964  01:56:08.0  35.760N  49.860E                      29   117   IS ORIGINAL DATA SOURCE =  ISC
                                                                                     8 STATION RECORDINGS USED IN SOLUTION

32    30 OCT 1973  16:38:52.8  37.011N  50.610E                      19   117   IS ORIGINAL DATA SOURCE =  ISC
                                                                                    23 STATION RECORDINGS USED IN SOLUTION

33     3 SEP 1962  02:08:26.0  35.750N  50.000E                            123   IS ORIGINAL DATA SOURCE =  BCIS
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| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 30 OCT 1973 | 15:59:30.8 | 36.946N | 50.706E | | | 4.10 | | 48 | 123 | IS | ORIGINAL DATA SOURCE = ISC<br>42 STATION RECORDINGS USED IN SOLUTION |
| 35 | 24 MAR 1963 | 12:43:58.0 | 37.000N | 48.000E | | | 5.70 | | | 124 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = SHL<br>MAGNITUDE AUTHORITY = LJU |
| 36 | 2 SEP 1962 | 07:12:02.0 | 35.600N | 49.200E | | | 4.88 | | | 126 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = MOS |
| 37 | 13 MAR 1975 | 17:33:12.7 | 37.082N | 50.698E | | | 4.40 | | 27 | 126 | IS | ORIGINAL DATA SOURCE = ISC<br>37 STATION RECORDINGS USED IN SOLUTION |
| 38 | 13 OCT 1962 | 10:23:38.0 | 35.750N | 50.070E | | | | | 35 | 127 | IS | ORIGINAL DATA SOURCE = ISS |
| 39 | 2 DEC 1962 | 22:12:14.0 | 35.700N | 50.000E | | III | | | | 128 | IS | ORIGINAL DATA SOURCE = BCIS |
| 40 | 2 DEC 1962 | 22:21:28.0 | 35.700N | 50.000E | | III | 5.00 | | | 128 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = MOS |
| 41 | 2 DEC 1962 | 23:36:35.0 | 35.700N | 50.000E | | V | | | | 128 | IS | ORIGINAL DATA SOURCE = BCIS |
| 42 | 25 AUG 1967 | 12:26:50.5 | 35.580N | 49.330E | | | 4.70 | | 55 | 128 | IS | ORIGINAL DATA SOURCE = ISC<br>49 STATION RECORDINGS USED IN SOLUTION |
| 43 | 4 SEP 1962 | 13:30:14.0 | 35.590N | 49.740E | | | | | 43 | 131 | IS | ORIGINAL DATA SOURCE = ISS |
| 44 | 13 OCT 1962 | 10:23:37.0 | 35.800N | 50.300E | | | 5.70 | | | 134 | IS | REPORTED FELT INFORMATION<br>ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = UPP |
| 45 | 1 SEP 1962 | 19:20:39.9 | 35.600N | 49.900E | | IX | 7.25 | | 27 | 135 | IS | ISC EFFECTS CODE = 010100<br>ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = PAS |
| 46 | 1 SEP 1962 | 20:27:37.0 | 35.600N | 49.900E | | | 4.50 | | | 135 | IS | ORIGINAL DATA SOURCE = BCIS<br>MAGNITUDE AUTHORITY = STR |
| 47 | 12 SEP 1962 | 02:16:42.0 | 35.500N | 49.900E | | | | | | 135 | IS | QUALITY = REPT<br>ORIGINAL DATA SOURCE = BCIS |
| 48 | 1 SEP 1962 | 19:20:40.0 | 35.580N | 49.880E | | | | | 29 | 136 | IS | ORIGINAL DATA SOURCE = ISS |
| 49 | 23 JUN 1967 | 13:15:08.0 | 35.500N | 49.600E | | | | | 38 | 138 | IS | ORIGINAL DATA SOURCE = ISC<br>6 STATION RECORDINGS USED IN SOLUTION |
| 50 | 15 MAY 1971 | 04:53:07.1 | 37.357N | 49.044E | | | 4.70 | | 50 | 139 | IS | ORIGINAL DATA SOURCE = ISC<br>44 STATION RECORDINGS USED IN SOLUTION |

| CAT. NO. | DATE DAY-MO-YEAR | TIME(GMT) HR-MIN-SEC | LAT | LONG | SL | INTEN (MM) | MAG | SM | H (KM) | DIS (KM) | Q S | LOCATION AND COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51 | 29 OCT 1965 | 15:59:42.1 | 37.900N | 48.700E | | | 4.60 | | 33 | 142 | IS | DATA OBTAINED VIA ISC<br>ORIGINAL DATA SOURCE = USCGS<br>11 STATION RECORDINGS USED IN SOLUTION |
| 52 | 8 NOV 1965 | 03:14:12.8 | 36.100N | 50.740E | | | 4.80 | | 41 | 143 | IS | ORIGINAL DATA SOURCE = ISC<br>55 STATION RECORDINGS USED IN SOLUTION |
| 53 | 19 AUG 1957 | 07:22:27.0 | 38.000N | 49.000E | | | | | | 144 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS |
| 54 | 19 AUG 1957 | 07:22:27.0 | 38.000N | 49.000E | | | | | | 144 | IS | ORIGINAL DATA SOURCE = BCIS |
| 55 | 3 NOV 1964 | 17:36:08.5 | 35.630N | 50.290E | | | 5.10 | | 42 | 148 | IS | ORIGINAL DATA SOURCE = ISC<br>59 STATION RECORDINGS USED IN SOLUTION |
| 56 | 11 APR 1975 | 14:26:46.4 | 35.649N | 50.354E | | | 4.70 | | 59 | 150 | IS | ORIGINAL DATA SOURCE = ISC<br>58 STATION RECORDINGS USED IN SOLUTION |
| 57 | 12 APR 1956 | 22:34:52.0 | 38.000N | 50.000E | | | 5.50 | | | 152 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = MOS |
| 58 | 8 FEB 1964 | 06:28:27.5 | 37.100N | 51.040E | | | 4.60 | | 40 | 156 | IS | ORIGINAL DATA SOURCE = ISC<br>37 STATION RECORDINGS USED IN SOLUTION |
| 59 | 1 SEP 1962 | 20:27:36.0 | 35.300N | 49.600E | | | 4.50 | | | 160 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = STR |
| 60 | 2 SEP 1962 | 13:21:18.0 | 38.000N | 48.500E | | | 4.00 | | | 160 | IS | DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = MOS<br>MAGNITUDE AUTHORITY = MOS |
| 61 | 1 SEP 1962 | 19:20:22.0 | 35.750N | 48.000E | | IX | 7.75 | | | 163 | IS | ISC EFFECTS CODE = 010100<br>DATA OBTAINED VIA BCIS<br>ORIGINAL DATA SOURCE = QUE<br>MAGNITUDE AUTHORITY = BRK |
| 62 | 9 NOV 1944 | 19:39:40.0 | 38.000N | 48.400E | | | | | | 164 | IS | ORIGINAL DATA SOURCE = ISS |
| 63 | 6 MAY 1957 | 15:06:47.0 | 36.000N | 51.000E | | | | | | 169 | IS | ORIGINAL DATA SOURCE = BCIS |
| 64 | 6 MAY 1957 | 15:06:47.0 | 36.000N | 51.000E | | | | | | 169 | IS | DATA OBTAINED VIA USE<br>ORIGINAL DATA SOURCE = CGS |