

GEOPHYSICAL INVESTIGATION OF THE
SAN JACINTO VALLEY, RIVERSIDE COUNTY, CALIFORNIA

for
EASTERN MUNICIPAL WATER DISTRICT
HEMET, CALIFORNIA

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INTRODUCTION

The San Jacinto fault is one of the most active faults in southern-California. This report presents the findings of a gravity and seismic survey conducted along a portion of the San Jacinto fault zone, near the cities of San Jacinto and Hemet, Riverside County, California.

A brief discussion of the geology of the area of investigation will be presented to assist in understanding the subsurface information obtained from the geophysical work.

The gravity survey was effective in outlining the buried bedrock topography on the Hemet side of the San Jacinto valley where depth to bedrock is generally less than 1,000 feet. On the San Jacinto side of the valley depth to bedrock was found to be in excess of 3,500 to 4,000 feet and difficult to accurately determine gravimetricly. The gravity work did indicate the location of the deepest portion of the valley and this location was the first to be seismicly investigated. The finding was a two mile depth to bedrock in the three mile wide rift between the Casa Loma and Claremont branches of the San Jacinto fault zone.

The effects of the geophysical findings on the ground water geology and engineering geology of the valley are discussed in the last section of this report.

GEOLOGY

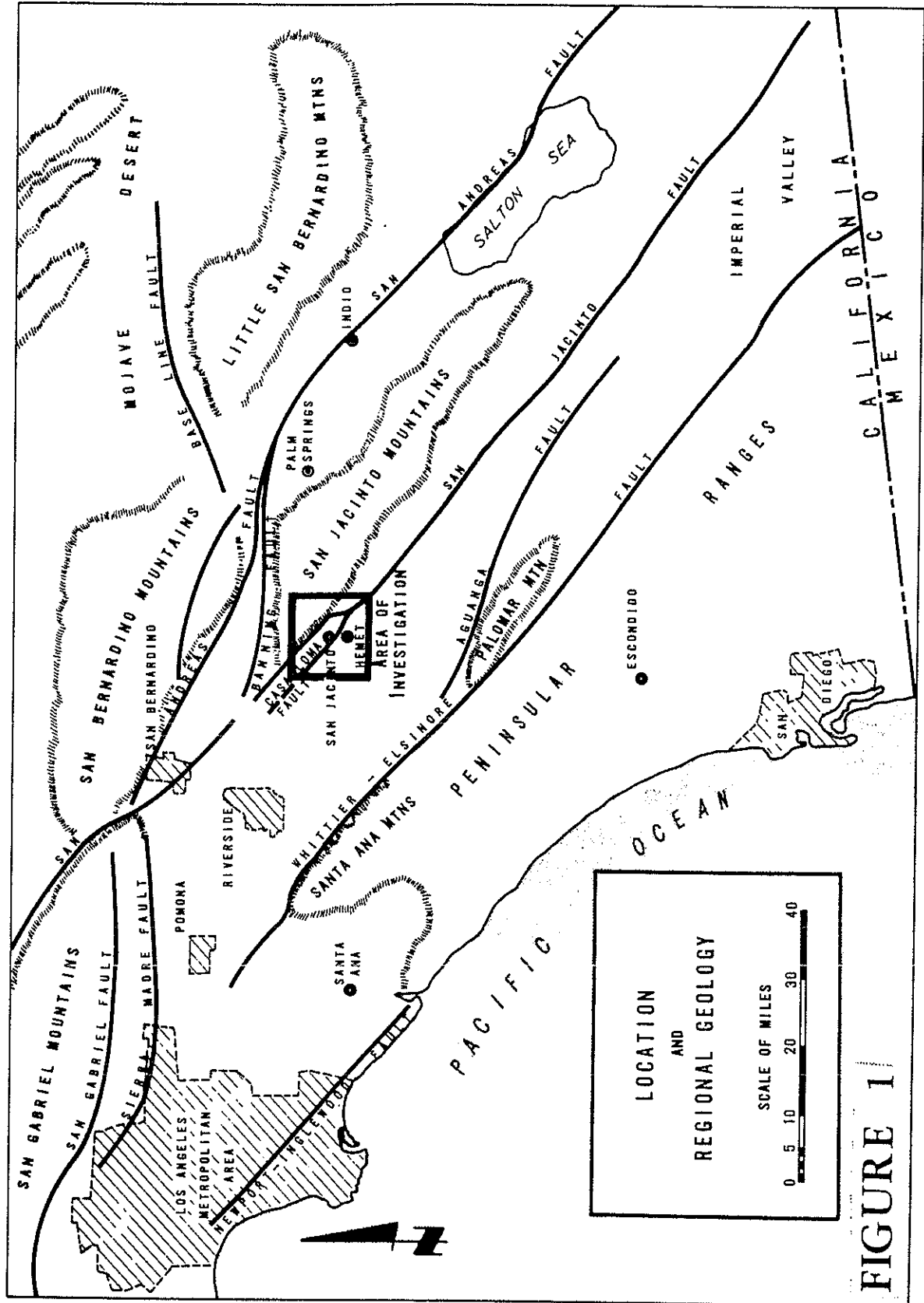
REGIONAL GEOLOGY

Figure 1 indicates the regional geology and the location of the area of investigation.

The area of investigation is at the northern end of the Peninsular Range. Obliquely traversing the Peninsular Range are several parallel fault zones trending northwest-southeast. Through the area of investigation passes the San Jacinto fault zone, to the northeast is the San Andreas fault zone and to the southwest the Elsinore fault zone. On the basis of seismicity in historical time the San Jacinto fault zone is perhaps the most active in southern California (Allen et al., 1966). Between the San Jacinto and Elsinore fault zones is the Perris Block, a relatively stable geomorphic unit named by English (1926) and its geomorphology described by Dudley (1936). The Hemet side of the San Jacinto Valley is on the edge of the Perris Block and the San Jacinto side of the valley, on the San Jacinto fault zone.

In the San Jacinto fault zone beneath San Jacinto is a rift or graben bounded by the Casa Loma and Claremont branches of the fault system.

A similar structure exists in the Elsinore fault zone. A lava, probably of late Pliocene or early Pleistocene age, has been dropped at least 3,000 feet by faulting and covered by more than 2,400 feet of graben



filling sediments (Mann, 1955).

LOCAL GEOLOGY

The geologic relations in the area are largely controlled by faulting with alluvial soil filling against faulted blocks and to the southwest of the Casa Loma fault against remnant high points of metamorphic and igneous rocks. The alluvial soils are themselves cut by faults, some forming escarpments at the surface and others evidenced by anomalous ground-water conditions. Figure 2 is a brief sketch of the local geology and figure 3 presents bedrock elevations determined from well logs. In the area of investigation no wells have reached bedrock between the Casa Loma and Claremont faults.

Geologic Formations

The metamorphic rocks are mostly schists and gneisses. They have been assigned to the Paleozoic era by Larsen (1948).

The igneous rocks are mostly Cretaceous tonalites and granodiorites. These plutonics are of the southern California batholith and are described by Larsen.

Since the densities and especially the seismic velocities of the metamorphic and igneous rocks are similar, these rocks are not differentiated on the map. Both may be considered as impermeable nonwater-bearing rocks though for small water supplies the greater fracturing and generally greater depth of weathering in the metamorphics tend

to make them more productive than the igneous rock.

The early Quaternary -late Tertiary sediments of the area were divided into the Mt. Eden, San Timoteo, and Bautista formations and named by Frick ~~(1924)~~^b. Based on vertebrate faunas ^{he} assigned them to the upper lower Pliocene, late Pliocene and Pleistocene respectively. They are all poorly consolidated continental clastics generally of rather low permeability. These older sediments from Park Hill, Casa Loma, the hills east of Bautista wash, the Badlands to the northwest of the area of investigation, much of the Saboba reservation, and the sediments of the southwest side of the San Jacinto mountains.

The Recent-late Quaternary sediments fill much of the San Jacinto valley and most are ^{stream} channel deposits. Some thin silt and clay layers were caused by flooding and contemporaneous weathering increased the residual clay.

Faults

The Casa Loma fault forms the northeast boundary of the Perris block in the area of investigation. A Recent scarp exists along this fault trace from Casa Loma ^{hill} to Park Hill. It has a maximum height of over 20 feet, the northeast side having dropped relative to the southwest side. Deep trenches across this ~~fault~~ were dug ^{for} the Los Angeles and San Diego branches of the Colorado River ^A aqueduct

and these excellent exposures of the fault's Recent activity were ^{have been} described ^{by (2)(11)} by Buwalda (Bean, 1955) and by Proctor (1962). The fault hampers the flow of ground water; differences of as much as 50 feet in the water table have occurred across the fault immediately west of Park Hill.

To the south and southeast of Park Hill, Bean located a fault on geomorphic and hydrologic evidence. He named it the Bautista Creek fault. It has a scarp of a few feet to six feet in height, the northeast side having dropped relative to the southwest side. This fault has moved in the same sense as the Casa Loma and is well aligned with it. ~~The writer suggests~~ they are essentially the same fault.

With down-dropping of the area to the northeast of the fault, a closed topographic depression was created between the fault scarp and Park Hill. Later flooding, overflow, and erosion have ^{eroded} removed the segment of Recent scarp southwest of Park Hill. Bean continued the Bautista fault to the southeast of the valley and when the faults southeast of the valley were later studied by Sharp (1967), Sharp called this same fault the San Jacinto fault. Bean noted that the Bautista fault meets the Casa Loma fault west of Park Hill but felt there are many dissimilarities between them. He cited the absence of a low scarp along the Bautista fault in the alluvium and the lack of irregularity of trace in its exposures southeast of the valley. Hence he believed the Bautista fault to have marked strike-slip move-

ment as opposed to dip-slip movement on the Casa Loma fault. On the first point, Bean evidently did not notice the low scarp that does exist along a mile and a half of the Bautista fault. If the Bautista fault were to have a large dip-slip component in the San Jacinto valley, depth to basement would be much greater to the northeast of the fault and the gravity and seismic work investigated this question.

On the north side of the San Jacinto valley the Claremont branch of the San Jacinto fault zone is located at the contact between the valley fill and the steep metamorphic and igneous mountains to the north (Eraser, 1931 and Bean, 1955). The mountains to the north have been elevated along this fault to 3,000 feet above the valley floor. Minimal erosion on the mountain face and extremely small alluvial fans at its foot indicate the recentness of this movement.

Near the center of the valley ~~Bean~~ Located the Park Hill fault along the north side of Park Hill and, continued to the southeast, a northwest trending canyon located between Bautista Creek and San Jacinto River. He noted that it does not appear to have an effect on ground water in the Recent sediments.

Landslides

Numerous landslides have occurred in the Bautista sediments. Recent occurrences are mostly the result of

embankment steepening by river erosion or faulting. Undoubtedly movement of many of these slides has been triggered by earthquakes. Rolfe and Strong (1918) reported some slides occurring during the 1918 earthquake.

Subsidence

Three forms of subsidence are occurring in the San Jacinto valley.

1) Tectonic lowering of the graben bounded by the Casa Loma and Claremont branches of the San Jacinto fault zone has created a closed topographic depression north of Lakeview. The depression has in the historical past been filled with flood waters to form a dry lake (Waring, 1919).

2) Down-dropping of approximately the same area has been taking place during the past thirty or so years as a result of ground water withdrawal (Fett et al., 1967). The rate of subsidence is currently about 0.1 foot per year and pipelines, roads, and structures at the edge of the graben are being damaged. Numerous water wells in the graben have failed by excess axial compression and many more will be destroyed (Fett and Hamilton, 1968). The size and depth of the natural topographic depression north of Lakeview is increasing due to this new subsidence.

3) On the Hemet side of the valley soil collapse occurs beneath portions of the city of Hemet. When soil is deposited so loose as to have sufficient void space to hold enough water for the soil's liquid limit to be reached,

the soil possesses the potential hazard of collapse (~~Gibbs~~⁹ and Bara, 1967). Wind deposited silt is the probable local origin of these dangerous soils. No matter how small the foundation loading, if a structure's foundation does not extend below these soils, the structure will settle if the soil becomes saturated. This has occurred to several buildings in the city of Hemet and ~~will~~^{could} probably damage more in the future. It is quite possible that these soils exist at other locations in the San Jacinto valley but have gone unnoticed because of sparse building development in the past.

GRAVITY SURVEY

The gravitational attraction of the earth is not the same at all locations on the earth's surface. These differences result from the earth not being a perfect sphere with the same variation of density beneath all points on its surface. The main factors causing variations in the earth's gravitational attraction are the following:

1. the earth not being perfectly spherical,
2. acceleration from the earth's rotation on its axis,
3. differences in elevation and hence, differences in distance to the earth's center of gravity,
4. the additional attraction of the rock between sea level or datum and the observation location,
5. topographic irregularities causing a reduction in gravity because of the attraction of material higher than the observation location and lack of attraction of depressions in the topography below the observation location,
6. the gravitational attractions and earth tides caused by the moon and sun,
7. lateral variations in rock density.

A gravity survey ^{primarily} consists of measuring the pull of gravity at numerous locations in the area of interest, calculating the theoretical value of gravity at these locations and plotting the differences between theoretical and

measured gravity. If items 1 through 6 have been taken into consideration in the calculation of the theoretical gravity, the resulting anomaly is caused primarily by lateral variation in the density of the rock beneath the area of investigation.

This survey used ^aLaCoste and Romberg G-22 geodetic gravity meter. It is a portable, temperature regulated meter working on the zero-length spring principle. It is characterized by small drift without "tears" and capable of measuring relative gravity to better than one ten millionth of a "G."

The location of most gravity stations of this survey are indicated on figure 4. Some additional stations were occupied outside the area of investigation to obtain insight into the regional gravity anomaly. Station locations, elevations observed gravity, and anomalies are presented in tabular form in the appendix.

The gravity work presented here is only a portion of a larger project conducted by Dr. Gordon P. Eaton and the writer. ~~X~~ The gravity data of the larger project are being ~~X~~ reduced in detail by electronic computer. The gravity anomalies plotted here have been reduced by desk calculator. The resulting Bouguer anomaly is presented in figure 5. A small error has been introduced by ignoring the effect of topography. ~~X~~ Since most stations are on the rather flat

valley floor, this effect is quite small (~~from local topography.~~) Though the effect from distant topography such as the mountains north and east of the valley, ~~(the distant topographic effect)~~ can be removed with the "regional."

In the area of investigation, the primary causes of the anomaly are variation in the thickness of the valley filling sediments and variations in the thickness of the earth's crust. Since the crust is about thirty miles thick beneath the area of investigation, the regional anomaly produced by variation in the crust's thickness is very smooth compared to the anomaly produced by variation in the thickness of the valley sediments.

It is the anomaly caused by the valley sediments that is of interest for this investigation. To acquire this local anomaly, the regional anomaly must be removed from the total anomaly. ~~To remove the regional anomaly~~ ^{employed the procedure} there are some rather elaborate techniques which are being applied, with the aid of an electronic computer, to all the data of the above mentioned larger project. It will suffice for this study to approximate the regional anomaly by a linear decrease in gravity, going from the southwest edge of the valley to the northeast edge. The magnitude of this decrease has been adjusted to yield a local anomaly that is approximately zero in value on bedrock on both sides of the valley. The resulting anomaly, figure 6, is due primarily to

valley sediments. To the southwest of the Casa Loma fault this anomaly is approximately proportional to sediment thickness. To the northeast of the Casa Loma fault, the anomaly indicates sediment thickness of about 3,500 to 4,000 feet.

With sediment depths of 3,000 feet or more, the gravity method of determining depth to bedrock becomes more qualitative than quantitative unless sediment bulk densities are known in detail. The local anomaly is caused by contrast between sediment and bedrock bulk densities. Sediment bulk density increases with greater depth of burial, approaching the density of bedrock. Also, some sediments in the San Jacinto valley have, in the geologic past, been buried to depth greater than their present depth. Only sparse information is available on sediment bulk densities in the San Jacinto valley and none for depths greater than 1,000 feet.

The gravity anomaly indicates the deepest part of the valley to be approximately beneath the city of San Jacinto.

SEISMIC SURVEY

To more accurately determine the depth of the valley filling sediments in the San Jacinto valley, a seismic survey was conducted. The refraction method was used as it was the most straight forward for the equipment available and the geology.

The seismic velocity of granitic bedrock in the area of investigation was first determined. This was accomplished by Dr. Eaton, University of California at Riverside (UCR) students, and the writer with the writer's Texas Instrument EXPLORER system. Measurements were made on the northeast side of the Lakeview mountains, both across foliation and with foliation. The rock was found to be anisotropic, with minimum velocity about 14,500 feet per second across foliation and maximum velocity about 17,000 feet per second along foliation.

On two commercial seismic investigations in the area, ~~the writer~~ ^{the writer} measured the seismic velocity of unweathered metamorphic bedrock and found 15,000 to 16,000 feet per second to be typical. The metamorphics displayed less anisotropy than the foliated granitics.

LINE A

The first line profile, Line A, was located along the axis of the gravity low with the city of San Jacinto at the center of the line.

Drs. Shawn Biehler and Stewart Smith of the California Institute of Technology, Dr. Gordon Eaton of UCR, students of both schools and ~~the writer~~ performed the recording of Line A data from Shot Point 1. The shot point was at the northwest end of the line and was located in the San Jacinto river bed just west of the junction of Masacre Canyon creek with the river. The location of this shot point and the recording locations are plotted on figure 7. CIT supervised operations at Shot Point 1. Shot instant was radioed to recording units by utilizing CIT's tone generating blaster. Several seconds before shot time a 400 Hz tone was transmitted. This tone was interrupted at the precise instant of cap detonation. The tone signal was received at recording units and placed on records by auxiliary galvanometers. CIT, UCR, and ~~the writer's~~ recording locations are identified on figure 7 by the letters CIT, UCR, and JDF followed by their appropriate spread number.

Eastern Municipal Water District (EMWD) supplied explosives and the men and equipment to place the charges for all seismic work. Dynamite was used for the explosive agent for Shot Point 1. Charge size increased as recording locations became more distant. Maximum shot size was a little in excess of 500 pounds.

Waves refracted from the bedrock became first arrivals at approximately Shaver street and Mountain avenue, a dis-

tance of about six miles from the shot point. Distances from shot point to recording locations and their associated seismic travel times are tabulated in the appendix and plotted on figure 11.

To verify the bedrock depth determination of 10,400 feet obtained by the above work and to determine the dip of the bedrock, Line A was reversed. The reversal was performed by Dr. Eaton and the ^{Felt} ~~writer~~, with the aid of UCR students. The ~~writer's~~ ^{Felt} EXPLORER seismic equipment and tone blaster together with EMWD radio equipment were used for the reversal of Line A and all subsequent work.

The shot point, Shot Point 2, was at the southeast end of the line, in Bautista creek, just north of Cedar avenue. Recording locations for Shot Point 2 and the location of Shot Point 2 are plotted on figure 8. Distance and travel time data are tabulated in the appendix^X and plotted on figure 11. ^{SP.}

To economize on explosive costs, the ~~writer~~ instructed EMWD personnel ~~in the~~ use of ammonium nitrate - fuel oil explosive. This reduced explosive costs to about 18 percent that of conventional explosive.

To increase the efficiency of the explosive charges, no more than 120 pounds were placed in a single shot hole. When larger charges were needed, they were obtained by connecting two or more shot holes together with Primacord

detonating fuse. Thus, more energy went into seismic wave generation and less into the air. This also had the effect of keeping the predominant frequency of the seismic pulse close to that desired for optimum transmission and recording. Cratering was also reduced.

The two mile depth to bedrock was corrected to a depth of 8,000 feet by this reversal of line A. ~~_____~~

LINE B

With the assistance of EMWD, ~~the writer~~ performed three more deep seismic profiles in the upper portion of the San Jacinto valley.

Line B follows the Bautista creek - Bautista flood control channel from Shot Point 2, near the junction of ~~B~~ Bautista creek with the San Jacinto river, through Shot ~~32~~ Point 3, to Shot Point 4 at the mouth of Bautista canyon. Recording locations for Shot Points 2, 3, and 4 are plotted on figures 8, 9, and 10. The distance and travel time data are tabulated in the appendix and plotted on figure 12.

Except for Shot Point 2, size of charges was limited by cultural development.

LINE C

Lines C and D are at right angles to the predominant trend of faulting in the valley. Their locations were selected to detail the position of faults and amount of bedrock elevation difference across faults.

Line C is located between Shot Point 2 and Shot Point 5. Shot Point 5 is about two and a quarter miles southwest of Shot Point 2. The locations of these shot points and their associated recording locations are plotted on figures 8 and 10. Observations on Spread 1 of Shot Point 5 were supplemented by two small shots, one at the northeast end of Spread 1 and one about 750 feet northeast of the northeast end of Spread 1. The distance and travel time data are tabulated in the appendix and plotted on figure 13.

LINE D

Line D extends along the Lake Hemet Municipal Water District's flume from Bautista flood control channel^e, at Shot Point 3, to Shot Point 6, which is located on bedrock about a mile southwest of Shot Point 3. The locations of these shot points and their associated recording locations are plotted on figures 9 and 10. Observations on most of the spreads of Line D were supplemented by shots in the small reservoir near the center of section 20. The distance and travel time data are tabulated in the appendix and plotted on figure 14.

FINDINGS AND THEIR IMPLICATIONS

The gravity survey has determined, in a qualitative manner, the bedrock topography to the southwest of Casa Loma fault. The Bouguer anomaly with the regional removed, figure 6, shows good correlation between the magnitude of the local Bouguer gravity anomaly and bedrock depths obtained from well log information, figure 3. Based on well log information and mostly gravity information, the drainage patterns on the buried bedrock surface have been plotted on figure 15.

With the detailed processing and interpretation of this and Dr. Eaton's gravity data, it will be possible to quantitatively plot bedrock elevation.

Knowledge of bedrock configuration beneath the valley fill on the Hemet side of the Casa Loma fault is of prime importance for an understanding of ground water in the area. Wells with optimum specific capacity may be expected to occur where drilled to bedrock along the buried drainage courses on the bedrock surface. In these locations the sediments just above bedrock should be coarser grained than those just above the higher slopes or ridges of the bedrock.

The City of Hemet well near Stetson avenue and Gilbert street is an example of this principle. It is located near a trough in the gravity anomaly, and is quite probably located over the channel in the bedrock surface that drained

from the east, passing beneath this well site, then turned northward. The well passes through coarser grained sediments, predominantly subrounded fine gravel and coarse sand, in the one hundred and fifty feet immediately above bedrock. The specific capacity of the well is excellent and should remain good even if the water table is lowered, since the major zone of production is in the lowest portion of the well.

Though there are few bedrock outcrops between the Casa Loma fault and the hills on the south of the San Jacinto valley, prolonged overdraft of the valley's ground water has lowered the water table sufficiently for many buried bedrock hills and ridges to form "islands" and "peninsulas" rising above the water table, ~~but not above the surface of the sediments.~~ The area southeast of Florida avenue and San Jacinto street is such a region.

As a result of the many barriers ~~formed~~ by the irregular surface of the buried bedrock, a well of good specific capacity may lower the water table in its vicinity an abnormal amount if the well is located in an alcove and cut off on several sides by such barriers. If the water table continues to decline, these barriers become increasingly important in the prediction of the long term potential of a well site, and the buried drainage courses on the bedrock surface become increasingly important in the location of wells of

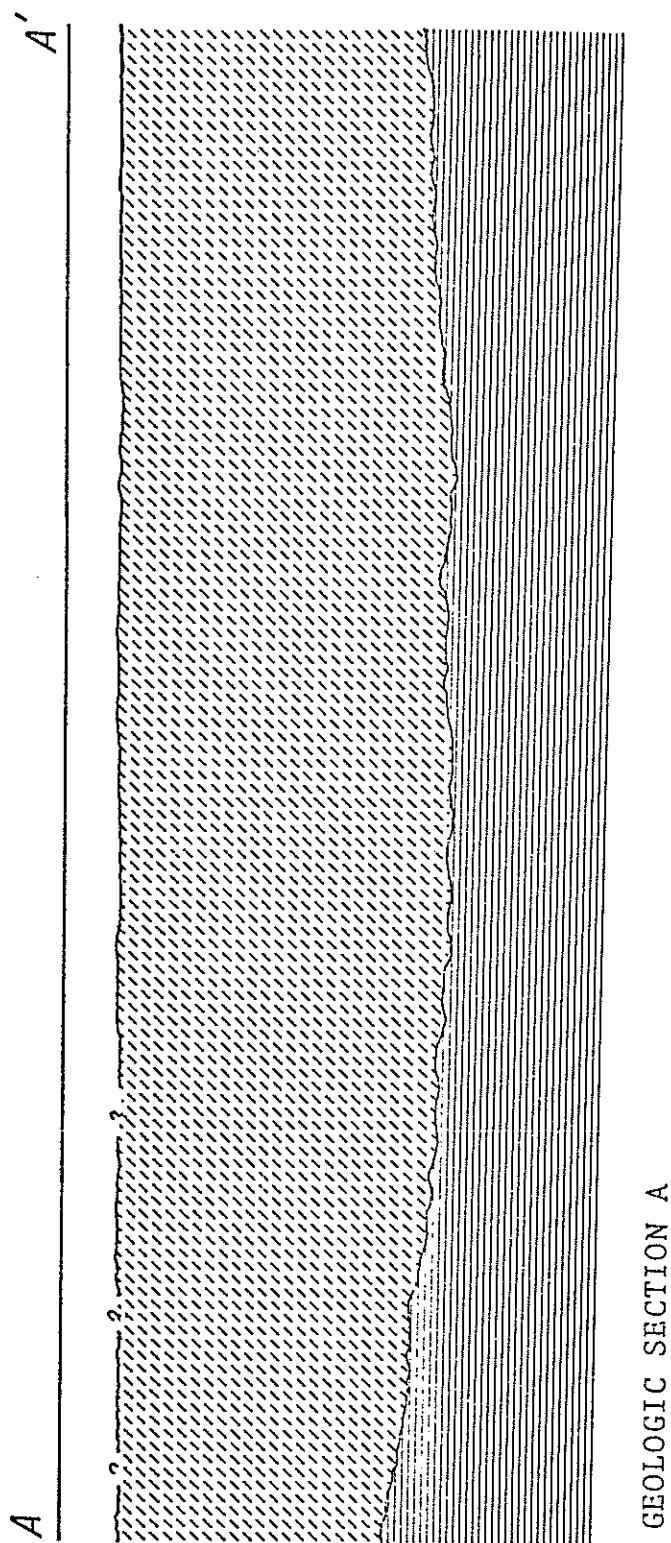
sufficient yield to be economical sources of water supply.

A knowledge of bedrock depth will be of value, in the future, for determining criteria of aseismic design of larger structures. Site conditions have a large effect on earthquake intensities. In the foreseeable future, building codes will allow variations from standard design, according to geological conditions beneath a site.

Bedrock depth information, supplemented with specialized seismic measurements, could be used to produce a seismicity microzoning of the valley.

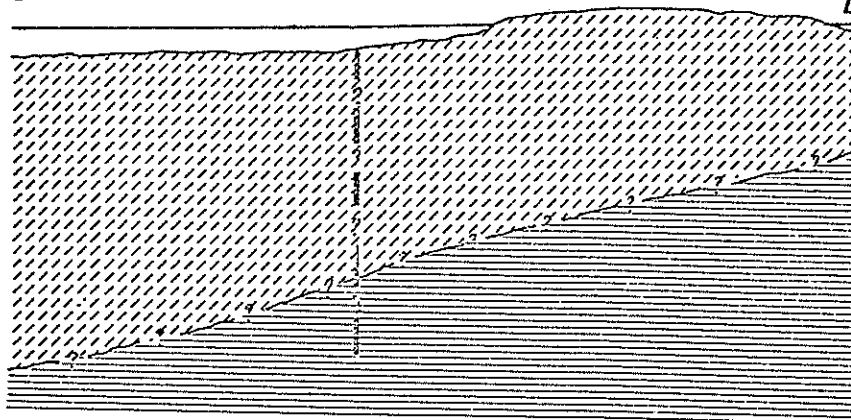
Based on the interpretation of the seismic data, and available subsurface information, five geologic cross sections of the valley have been constructed. The location of the geologic sections are plotted on figure 16. The sections constitute figures 17, 18, and 19. Figure 20 is a block diagram of the San Jacinto valley area.

Geologic section A, figure 17, is approximately along the alignment of seismic line A. The depth to bedrock is about 8,000 feet. The San Jacinto fault zone has dropped a wedge of bedrock, between the Claremont fault on the northeast side of the valley, and the Casa Loma fault that passes through the center of the valley. This spectacular rift or graben is continuing to increase in depth, as is evidenced by the recentness of faulting on both the Casa Loma and Claremont faults. The depth to the Bautista formation is possibly

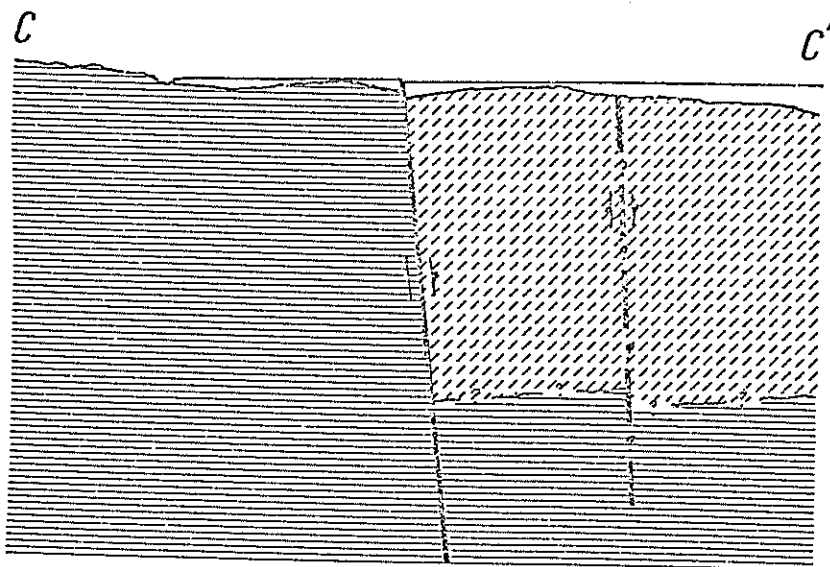


Key, symbols, and scale same as figure 2 (one mile to the inch horizontally and vertically)

B *B'* *FIGURE 18*



GEOLOGIC SECTION B



GEOLOGIC SECTION C

Key, symbols, and scale same as figure 2 (one mile to the inch horizontally and vertically)

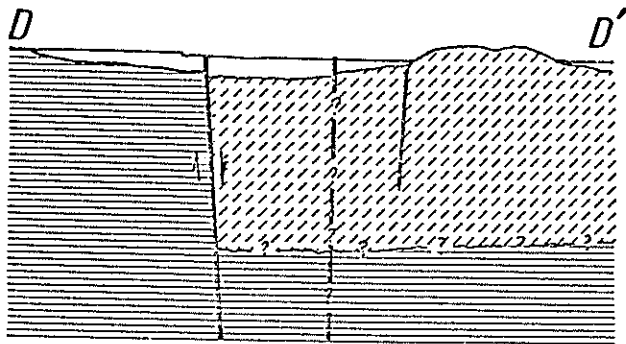
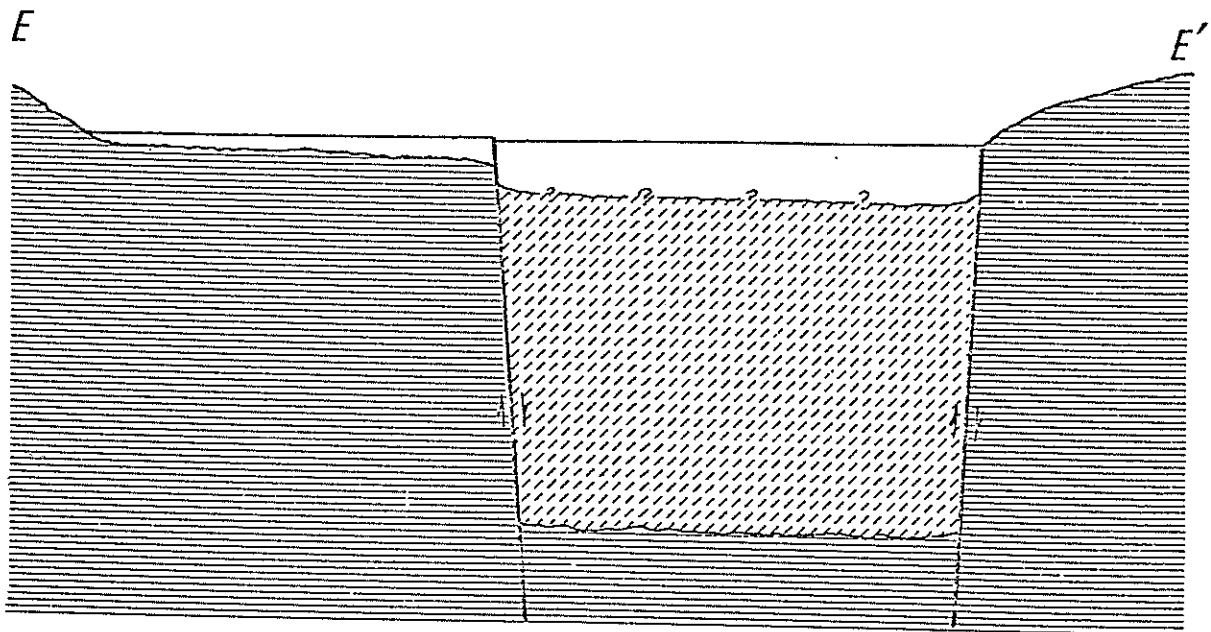


FIGURE 19

GEOLOGIC SECTION D



GEOLOGIC SECTION E

Key, symbols, and scale same as figure 2 (one mile to the inch horizontally and vertically)

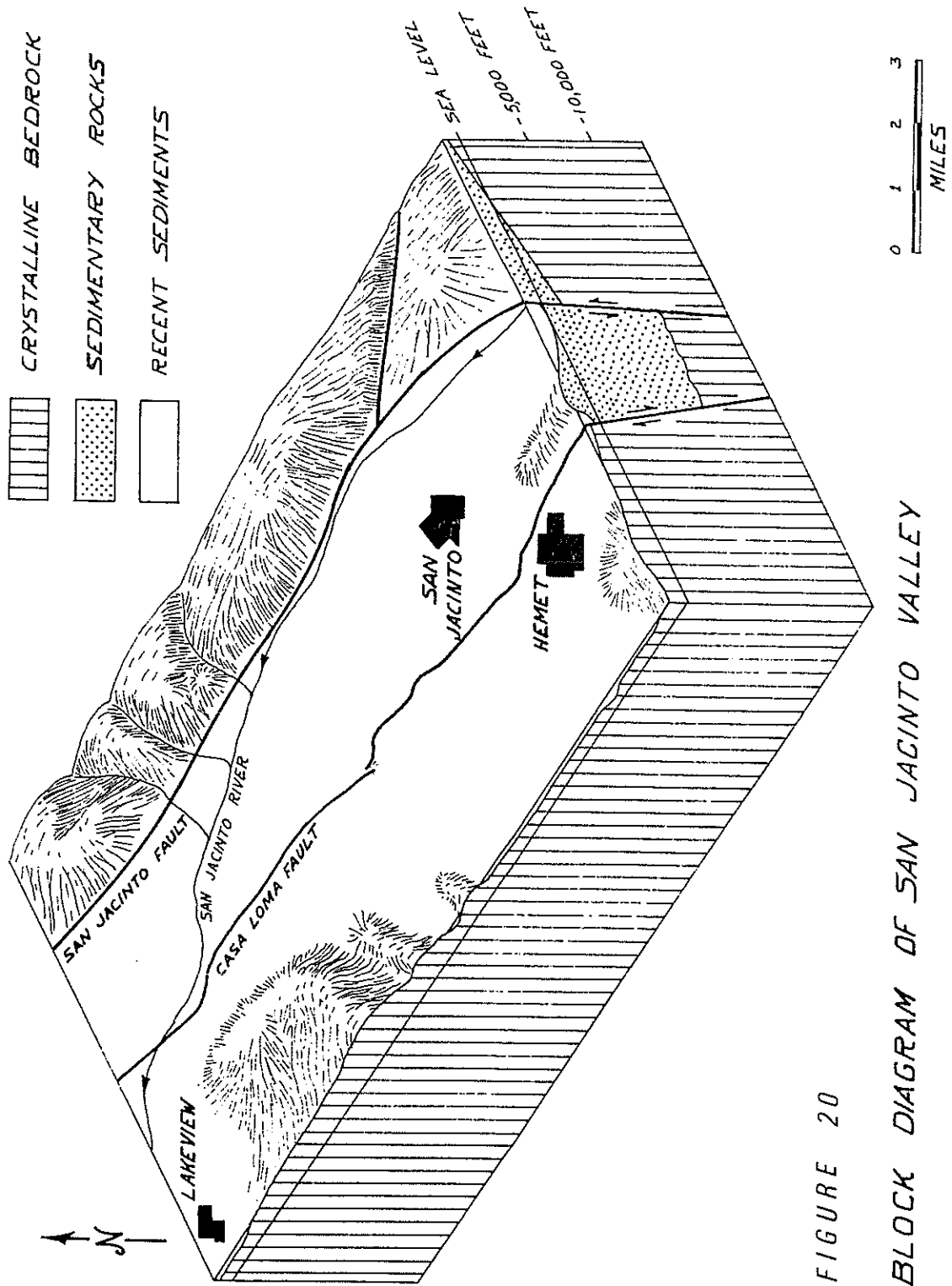


FIGURE 20

BLOCK DIAGRAM OF SAN JACINTO VALLEY

1,500 or more feet beneath the central and northwestern portion of line A. Near the southeastern end of the line it is probably 1,400 feet beneath the surface.

Geologic section B, figure 18, is approximately along the alignment of seismic line B. The depth to bedrock is probably about 4,500 feet beneath Shot Point 3. It is possible that the refracted wave, which becomes a first arrival approximately 14,400 feet from Shot Point 2, is not refracted from the bedrock beneath the line, but from the bedrock face of the San Jacinto - Bautista fault to the southwest. If this is the case, bedrock could be deeper than 4,500 feet beneath Shot Point 3. The Bautista formation begins at a depth of approximately 600 feet near the northwest end of section B and crops out along the southeastern portion of this section. Near the center of section B, a minor fault in the Bautista formation passes under the Recent alluvium. No seismic evidence of off-set in the Recent alluvium by this fault was obtained.

Geologic section C, figure 18, is along the seismic line C alignment and also extended to the southwest. At the center of this section is the Bautista fault. There is a few feet of Recent vertical off-set at the surface. On the southwest side of the fault, bedrock is at a depth of about 200 feet. On the northeast, bedrock depth is in excess of 3,000 feet, and probably much deeper. Further northeast, the Park Hill fault (~~Bean~~) is crossed. No seismic evidence

of off-set in the Recent sediments was obtained.

Geologic section D, figure 19, is along the alignment of seismic line D and extended to the northeast. From the hills south of the valley, the bedrock surface passes beneath the alluvium. At the San Jacinto - Bautista fault, beneath the D alignment, the bedrock surface is at a depth of 450 to 550 feet on the southwest. On the northeast side of this fault, bedrock is in excess of 1,400 feet and probably deeper than 4,000 feet. The surface of the Bautista formation reaches a maximum depth of about 550 feet between this fault and the hills to the northeast, which are composed of Bautista formation and capped, in places, with younger terrace forming sediments. No seismic evidence was obtained of off-set in the alluvium above the Bautista formation between the San Jacinto - Bautista fault and the hills northeast.

Geologic section E, figure 19, is based partly on seismic work of Dr. Eaton and the ~~writer~~^{Felt} that is not reported here in detail. This seismic work found the bedrock surface at a depth of about 380 feet midway between the Lakeview mountains and the Casa Loma fault. This depth increased to a depth of 500 to 600 feet near the Casa Loma fault. Bedrock depth northeast of the fault is probably 7,000 to 8,000 feet, based on seismic line A information.

The San Jacinto fault enters the valley at the mouth of Bautista canyon, continues northwest under the name "Bautista fault," and further northwest under the name "Casa Loma fault."

Fault movement appears to have an increasingly greater dip-slip component toward the northwest. Perhaps some future confusion might be avoided if this fault would be called Casa Loma fault from the mouth of Bautista canyon to the northwest, and the San Jacinto fault to the southeast of the canyon mouth.

~~Sharp~~ has mentioned that the San Jacinto fault zone has, in addition to many miles of right-lateral off-set, considerable vertical off-set, having dropped the area northeast with respect to that on the southwest. The same sense of vertical movement is true of the Casa Loma fault.

Though the Casa Loma fault is less obtrusive in surface appearance than the Claremont fault, it is a major active fault. Because of its more subtle appearance, it is perhaps the more dangerous fault, for houses and structures, such as the San Jacinto reservoir, have been built along this fault. Its scarp has provided enough topographic relief to make attractive building sites.

Park Hill and Casa Loma are probably fault slivers. Geomorphically, Park Hill appears to be bounded on its northeast by a fault, named the Park Hill fault. Though the existence of the Park Hill fault is most likely, there does not seem to be any definite evidence of its existence or non-existence.

Because of the activeness and size of the Casa Loma

and Claremont faults, serious consideration and carefull design should be used in structures and improvements near these faults. Both surface disruption and severe seismic vibration are to be expected.

Future deep seismic investigation in the area can be performed with substantial savings in time and explosives if a greater number of recording channels are used and if the recording locations at greater distance from the shots or in areas of high background noise utilize multiple detectors for each channel.

Use of multiple detectors decreases the minimum size of shot required for a clear signal. This decrease is approximately inversely proportional to the number of detectors per channel, if the detectors for one channel are far enough apart that there is zero correlation of background noise between the detectors. Tomoda's (1956) method for calculating the correlation coefficient was applied to several test recordings of background noise in the San Jacinto vally.

For much of the San Jacinto valley and for much of the frequency spectrum of interest for refraction recording at moderate depths, a detector spacing of fifty feet has small correlation. For the very deepest work, the lower frequency refracted signal would require detector spacing of about 100 feet for small correlation of background noise at these lower frequencies.

Recording during the early morning hours would also help avoid excessive background noise and reduce the minimum shot size required for a clear signal.

ACKNOWLEDGEMENT

Drs. Shawn Biehler and Stewart Smith of California Institute of Technology, together with some of their students, supervised shotpoint operation at Shot Point 1 and recorded about half the data of Line A from Shot Point 1.

Dr. Eaton and the writer, with the aid of University of California at Riverside graduate students, recorded the remainder of the data of Line A from Shot Point 1 and all of the data of Line A from Shot Point 2.

Eastern Municipal Water District supplied explosives and the men and equipment for planting the explosives. The District also supplied radio equipment for transmitting shot time information and coordinating recording and shot point work.

Field assistants were provided by the District to assist the writer with Lines B, C, and D.

James Linehan of the District coordinated all work.

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APPENDIX: GRAVITY DATA

- Column 1: Station number
- Column 2: Latitude in degrees, minutes, and hundredths of a minute (example: 33403 is $33^{\circ} 44.03'$)
- Column 3: Longitude
- Column 4: Elevation in tenths of a foot if followed by a T and in feet if followed by a U (example: 17360T is 1736.0 feet above sea level; 1717U is 1717 feet above sea level)
- Column 5: Observed gravity minus 978,000.00 milligals (example: 143737 is 979,437.37 milligals)
- Column 6: Theoretical gravity at sea level minus 978,000.00 milligals (example: 163921 is 979,639.21 milligals)
- Column 7: Free air anomaly in hundredths of a milligal (example: -3855 is -38.55 milligals)
- Column 8: Bouguer anomaly in hundredths of a milligal plus 1,000.00 milligals (example: 90318 is $1,000.00 - 903.18 = -96.82$ milligals) 2.67 rock density used for correction
- Column 9: Bouguer anomaly, as above, but with 2.00 rock density used for correction.

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JF 101	334403	1165564	17360T	143737	163921	-3855	90318	91780	
JF 102	334410	1165564	17275T	143609	163930	-4072	90133	91588	
JF 103	334422	1165564	17218T	143414	163947	-4338	89886	91335	
JF 104	334433	1165564	1717U	143247	163962	-4566	89674	91120	
JF 105	334444	1165564	1711U	143106	163978	-4778	89482	90922	
JF 106	334453	1165564	1708U	142950	163990	-4975	89295	90733	
JF 107	334465	1165564	17041T	142810	164007	-5168	89117	90551	
JF 108	334476	1165564	1701U	142678	164022	-5344	88951	90383	
JF 109	334487	1165564	1699U	142570	164037	-5486	88815	90245	
JF 110	334497	1165564	1696U	142464	164051	-5635	88677	90105	
JF 111	334508	1165564	16934T	142559	164066	-5580	88741	90166	
JF 112	334508	1165537	16980T	142268	164066	-5827	88478	89907	
JF 113	334487	1165537	17070T	142330	164037	-5651	88623	90060	
JF 114	334476	1165537	17110T	142397	164022	-5532	88728	90169	
JF 115	334465	1165537	17150T	142513	164007	-5362	88885	90328	
JF 116	334455	1165537	17210T	142637	163993	-5168	89056	90506	
JF 117	334444	1165537	1724U	142808	163978	-4954	89261	90712	
JF 118	334434	1165537	1727U	142973	163964	-4746	89458	90913	
JF 119	334422	1165537	17275T	143163	163947	-4535	89670	91124	
JF 120	334412	1165537	1738U	143298	163933	-4287	89881	91345	
JF 121	334400	1165537	17425T	143520	163916	-4006	90146	91613	
JF 122	334381	1165512	1765U	143475	163890	-3814	90272	91756	
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JF 124	334400	1165512	1757U	143152	163916	-4238	89871	91340	
JF 125	334409	1165512	17521T	143011	163929	-4438	89690	91164	
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JF 127	334444	1165512	1735U	142531	163978	-5127	89057	90516	
JF 128	334465	1165512	17208T	142280	164007	-5541	88694	90141	
JF 129	334487	1165512	17138T	142088	164037	-5820	88430	89871	
JF 130	334530	1165512	16935T	141867	164097	-6300	88034	89456	
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JF 133	334575	1165485	1671U	141830	164159	-6612	87825	89221	
JF 134	334552	1165485	16885T	141754	164127	-6492	87873	89287	
JF 135	334531	1165484	17010T	141733	164098	-6366	87954	89380	
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JF 140	334487	1165395	1757U	141485	164037	-6026	88115	89585	
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JF 147	334466	1165427	1761U	141591	164008	-5853	88274	89748	
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JF 149	334444	1165459	1761U	141938	163978	-5476	88628	90107	
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JF 153	334378	1165398	1836U	142025	163886	-4591	89274	90814	
JF 154	334378	1165450	18021T	142763	163886	-4173	89703	91307	
JF 155	334378	1165484	1782U	143130	163886	-3985	90053	91549	
JF 156	334422	1165616	1695U	143950	163947	-4045	90256	91686	
JF 157	334422	1165642	1677U	144209	163947	-3964	90393	91809	
JF 158	334422	1165668	16672T	144434	163947	-3831	90553	91962	
JF 159	334421	1165694	16526T	144650	163946	-3751	90683	92080	
JF 160	334421	1165720	16402T	144827	163946	-3691	90774	92163	
JF 161	334421	1165747	1628U	144974	163946	-3659	90849	92227	
JF 162	334421	1165772	16185T	145128	163946	-3593	90940	92312	
JF 163	334421	1165799	1606U	145259	163946	-3581	90992	92354	
JF 164	334420	1165825	15943T	145403	163944	-3545	91067	92419	
JF 165	334420	1165851	1582U	145575	163944	-3489	91157	92500	
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JF 216	334378	1165616	16903T	144344	163886	-3643	90681	92106	
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JF 218	334378	1165668	16704T	144660	163886	-3514	90866	92276	
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JF 220	334377	1165720	16464T	144969	163885	-3430	91020	92413	
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JF 225	334398	1165825	1594U	145439	163914	-3482	91133	92484	
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JF 230	334377	1165877	15672T	145816	163885	-3327	91372	92702	
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JF 235	334338	1165616	17149T	144415	163830	-3285	90963	92407	
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JF 237	334359	1165668	1684U	144774	163860	-3246	91089	92510	
JF 238	334506	1165929	15586T	145692	164064	-3711	91008	92334	
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JF 260	334550	1165930	1549U	145684	164125	-3871	90883	92200	
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JF 291	334636	1165931	15354T	145488	164244	-4314	90494	91797	
JF 292	334636	1165957	15315T	145812	164244	-4026	90795	92094	
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JF 296	334572	1165983	1534U	146124	164155	-3603	91200	92504	
JF 297	334549	1165983	15373T	146098	164123	-3565	91224	92532	

	1	2	3	4	5	6	7	8	9
JF 298	334484	1165982	1539U	146116	164033	-3441	91341	92651	
JF 299	334506	1165983	15412T	146083	164064	-3484	91290	92601	
JF 300	334526	1165983	1537U	146084	164091	-3551	91239	92547	
JF 301	334572	1165955	1537U	145894	164155	-3804	90994	92300	
JF 302	334572	1165930	15445T	145662	164155	-3966	90807	92118	
JF 303	334572	1165903	1552U	145490	164155	-4067	90683	92001	
JF 304	334572	1165878	15590T	145324	164155	-4167	90563	91886	
JF 305	334550	1165903	1556U	145531	164125	-3957	90777	92097	
JF 306	334550	1165955	1545U	145870	164125	-3722	91046	92359	
JF 307	334594	1165957	1536U	145860	164186	-3878	90923	92228	
JF 308	334594	1165930	15414T	145611	164186	-4076	90707	92016	
JF 309	334594	1165903	1548U	145393	164186	-4233	90531	91845	
JF 310	334524	1165878	15562T	145233	164186	-4315	90425	91744	
JF 311	334500	1165590	16890T	142793	164055	-5375	88944	90369	
JF 312	334487	1165720	1690U	142886	164037	-5255	89061	90487	
JF 313	334415	1165590	1693U	143161	164007	-4921	89385	90814	
JF 314	334444	1165590	1705U	143396	163978	-4544	89720	91159	
JF 315	334422	1165590	1710U	143684	163947	-4179	90070	91513	
JF 316	334399	1165590	1710U	144009	163915	-3822	90429	91871	
JF 317	334377	1165590	1704U	144190	163885	-3667	90611	92047	
JF 318	334356	1165589	1714U	144213	163855	-3520	90729	92172	
JF 319	334338	1165589	1725U	144246	163830	-3359	90856	92308	
JF 320	334528	1165930	1554U	145668	164094	-3809	90928	92249	
JF 321	334614	1165930	1539U	145555	164213	-4183	90608	91915	
JF 322	334659	1165931	1533U	145361	164276	-4406	90321	91621	
JF 323	334680	1165933	15238T	145974	164305	-3998	90847	92141	
JF 324	334680	1165957	1527U	145597	164305	-4345	90497	91791	
JF 325	334681	1165932	15308T	145102	164306	-4806	90024	91321	
JF 326	334681	1165905	1521U	144702	164306	-5297	89571	90859	
JF 327	334681	1165866	15240T	144012	164306	-5959	88906	90194	
JF 328	334682	1165826	15312T	143497	164308	-6408	88445	89737	
JF 329	334682	1165800	1541U	143203	164308	-6610	88210	89510	
JF 330	334682	1165774	15485T	142963	164308	-6780	88021	89326	
JF 331	334682	1165748	1557U	142794	164308	-6868	87913	89223	
JF 332	334652	1165702	15755T	142643	164266	-6804	87919	89243	
JF 333	334652	1165661	1594U	142407	164266	-6866	87793	89134	
JF 334	334552	1165607	16100T	142236	164127	-6748	87852	89207	
JF 335	334116	1165725	1679U	145395	163523	-2335	92029	93444	
JF 336	334323	1165595	17174T	144446	163810	-3210	91041	92483	
JF 337	334321	1165563	1724U	144280	163807	-3311	90937	92380	
JF 338	334336	1165459	1852U	143037	163828	-3371	90432	91987	
JF 339	334357	1165505	1801U	143502	163857	-3414	90562	92074	
JF 340	334529	117 213	15072T	147890	164095	-2029	92861	94143	
JF 341	335026	117 397	1491U	147839	164786	-2922	92055	93315	
JF 342	334702	1165932	1518U	144864	164336	-5193	89681	90967	
JF 343	334724	1165932	15141T	144569	164366	-5556	89332	90615	
JF 344	334745	1165932	15053T	144331	164395	-5905	89020	90293	
JF 345	334768	1165932	15001T	144097	164427	-6221	88725	89993	
JF 346	334824	1165932	1495U	143693	164505	-6750	88225	89486	

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JF 347	334848	1165926	14895T	143569	164538	-6959	88049	89302	
JF 348	334863	1165906	14890T	143435	164559	-7119	87906	89155	
JF 349	334897	1165906	1486U	143474	164606	-7155	87904	89144	
JF 350	335003	1165920	1496U	144513	164754	-6169	88923	90155	
JF 351	334525	117 697	1722U	147962	164090	70	94236	95700	
JF 352	334635	117 538	2219U	145455	164243	2084	94572	96457	
JF 353	334802	117 538	1760U	147910	164474	-10	94031	95527	
JF 354	334436	1165720	16385T	144834	163966	-3721	90750	92137	
JF 355	334385	1165720	1642U	144940	163896	-3511	90953	92342	
JF 356	334376	1165881	1568U	145835	163883	-3299	91397	92728	
JF 357	334376	1165929	1550U	146112	163883	-3192	91558	92876	
JF 358	334285	1165929	1562U	146680	163757	-2385	92327	93654	
JF 359	334332	1165928	1546U	146467	163822	-2814	91052	93265	
JF 360	334398	1165929	1549U	146056	163914	-3287	91466	92782	
JF 361	334419	1165929	1550U	146039	163943	-3324	91426	92743	
JF 362	334376	117 351	15259T	146799	163883	-2732	92092	93391	
JF 363	334409	117 29	1520U	146730	163929	-2902	91942	93236	
JF 364	334463	117 351	15220T	146645	164004	-3043	91795	93091	
JF 365	334484	117 35	1524U	146584	164033	-3114	91717	93014	
JF 366	334506	117 35	1524U	146556	164064	-3173	91658	92955	
JF 367	334506	117 5	1532U	146329	164064	-3325	91481	92785	
JF 368	334506	1165954	1549U	145856	164064	-3637	91115	92432	
JF 369	334572	1165825	1577U	144718	164155	-4604	90074	91410	
JF 370	334592	1165825	15635T	144593	164183	-4884	89841	91165	
JF 371	334620	1165826	15410T	144264	164222	-5463	89342	90646	
JF 372	334637	1165801	15415T	143648	164245	-6098	88711	90014	
JF 373	334605	1165773	15595T	143747	164201	-5785	88960	90278	
JF 374	334547	1165574	1669U	142295	164120	-6127	88284	89686	
JF 375	334561	1165596	1653U	142390	164140	-6201	88247	89640	
JF 376	334579	1165639	16295T	142655	164165	-6182	88356	89727	
JF 377	334592	1165672	1615U	142783	164183	-6210	88363	89725	
JF 378	334592	1165648	1618U	142662	164183	-6302	88260	89624	
JF 379	334592	1165625	1627U	142443	164183	-6436	88111	89480	
JF 380	334616	1165592	1625U	142173	164216	-6759	87797	89163	
JF 381	334616	1165635	16115T	142294	164216	-6664	87939	89294	
JF 382	334633	1165701	1583U	142715	164240	-6635	88061	89392	
JF 383	334634	1165659	1595U	142459	164241	-6780	87874	89216	
JF 384	334634	1165635	1603U	142342	164241	-6821	87824	89168	
JF 385	334682	1165604	1604U	142279	164308	-6942	87722	89061	
JF 386	334703	1165626	1594U	142335	164337	-7009	87696	89025	
JF 387	334724	1165583	1595U	142566	164366	-6788	87939	89262	
JF 388	334744	1165557	1632U	142750	164394	-6293	88366	89706	
JF 390	334861	1165664	-0	143155	164556	-21401	80825	80266	
JF 391	334897	1165752	-0	143791	164606	-20815	81246	80729	
JF 392	334897	1165828	15035T	143401	164606	-7063	88050	89276	
JF 393	334866	1165828	15125T	143148	164563	-7189	87834	89083	
JF 394	334816	1165828	1519U	143011	164494	-7195	87746	89015	
JF 395	334787	1165849	1521U	143137	164454	-7010	87890	89170	
JF 396	334772	1165863	1520U	143319	164433	-6817	88078	89359	

	1	2	3	4	5	6	7	8	9
JF 397	334724	1165826	1532U	143196	164366	-6760	88095	89386	
JF 398	334583	1165773	15665T	144145	164170	-5291	89429	90754	
JF 399	334575	1165722	1631U	143343	164159	-5475	89027	90407	
JF 400	334574	1165705	1614U	143290	164158	-5687	88881	90244	
JF 401	334572	117	35 1521U	146490	164155	-3359	91486	92780	
JF 402	334637	117	35 1517U	146602	164245	-3374	91488	92777	
JF 403	334682	117	35 1515U	146497	164308	-3561	91311	92598	
JF 404	334723	117	36 1510U	146313	164365	-3849	91038	92321	
JF 405	334798	117	36 1496U	145410	164469	-4987	89957	91226	
JF 406	334762	117	36 1502U	145866	164419	-4425	90403	91768	
JF 407	334723	1165984	15161T	145470	164365	-4634	90238	91525	
JF 408	334723	1165957	1513U	145053	164365	-5081	89811	91093	
JF 409	334747	1165801	15365T	142912	164398	-7034	87819	89110	
JF 410	334762	1165783	1539U	142789	164419	-7154	87699	88990	
JF 411	334725	1165748	1556U	142646	164368	-7086	87709	89015	
JF 412	334791	1165749	1543U	142744	164459	-7202	87685	88968	
JF 413	334811	1165749	1540U	142815	164487	-7186	87741	89014	
JF 414	334811	1165723	1548U	142822	164487	-7105	87816	89091	
JF 415	334827	1165703	1543U	143022	164509	-6973	88043	89293	
JF 416	334805	1165678	1547U	142905	164479	-7023	87963	89221	
JF 417	334757	1165723	1557U	142592	164412	-7175	87644	88944	
JF 418	334749	1165670	15745T	142531	164401	-7060	87724	89033	
JF 419	334726	1165670	15815T	142461	164369	-7033	87704	89025	
JF 420	334703	1165670	15815T	142392	164337	-7069	87655	88979	
JF 421	334682	1165669	1587U	142383	164308	-6998	87700	89031	
JF 422	334682	1165702	15745T	142527	164308	-6971	87768	89088	
JF 423	334666	1165702	1574U	142459	164286	-7022	87708	89031	
JF 425	334667	1165637	1597U	142311	164287	-6954	87718	89055	
JF 426	334780	117	21715093T	147554	164444	-2693	92228	93502	
JF 424	334305	1165825	1587U	142414	163785	-6443	88203	89546	

SEISMIC DATA - LINE A

Spread	Distance*	Time	Spread	Distance	Time
UCR-I	74 feet	0.057	CIT-I	13,700	2.184
	260	0.092		13,900	2.212
	469	0.133		14,100	2.238
	678	0.177		14,300	2.266
	883	0.208		14,500	2.293
	1094	0.247		14,700	2.313
	1392	0.284		14,900	2.342
	1553	0.320		15,100	2.372
	1763	0.358	CIT-II	15,300	2.408
	1970	0.394		15,500	2.429
	2176	0.429		15,700	2.451
	2384	0.468		15,900	2.471
UCR-II	9,000	1.522		16,100	2.502
	9,200	1.556		16,300	2.520
	9,400	1.589		16,500	2.544
	9,600	1.623		16,700	2.562
	9,800	1.652	CIT-III	18,100	2.731
	10,000	1.674		18,300	2.761
	10,233	1.710		18,500	2.776
	10,438	1.731		18,700	2.797
	10,641	1.764		18,900	2.808
	10,843	1.794		19,100	2.838
	11,049	1.820		19,300	2.864
	11,250	1.841		19,500	2.883
JDF-I	11,250	1.841	JDF-II	18,785	2.793
	11,349	1.862		18,885	2.809
	11,448	1.873		18,985	2.823
	11,547	1.887		19,085	2.836
	11,646	1.906		19,185	2.853
	11,745	1.919		19,285	2.861
	11,844	1.929		19,385	2.871
	11,943	1.943		19,485	2.871
	12,042	1.959		19,585	2.885
	12,141	1.976		19,685	2.903
	12,240	1.991		19,785	
	12,340	2.006		19,885	2.925

* Distance from Shot Point 1 at northwest end of line

Line A continued

Spread	Distance	Time	
CIT-IV	19,900	2.947	
	20,100	2.967	
	20,300	3.001	
	20,500	3.035	
	20,700	3.052	
	20,900	3.067	
	21,100	3.089	
CIT-V	28,900	3.789	
	29,100	3.809	
	29,300	3.823	
	29,500	3.842	
	29,700	3.862	
	29,900	3.875	
	30,100	3.897	
	30,300	3.911	
CIT-VI	31,100	4.038	
	31,300	4.044	
	31,500	4.075	
	31,700	4.106	
	31,900	4.139	
	32,100	4.154	
	32,300	4.176	
	32,500	4.188	
JDF-III	34,800	4.348	4.429
	34,900	4.354	4.438
	35,000	4.357	4.441
	35,100	4.360	4.447
	35,200	4.371	4.454
	35,300	4.380	4.456
	35,400	4.379	4.462
	35,500	4.383	4.467
	35,600		
	35,700		
	35,800	4.390	
	35,900		

Line A continued

Spread	Distance*	Time	Spread	Distance	Time
1	1,300	0.470	4	7,936	1.451
	1,490	0.492		8,125	1.478
	1,680	0.515		8,314	1.509
	1,870	0.535		8,503	1.530
	2,060	0.552		8,692	1.557
	2,250	0.580		8,881	1.588
	2,450	0.615		9,070	1.624
	2,620	0.645		9,259	1.655
	2,810	0.673		9,448	1.679
	3,000	0.706		9,637	1.715
	3,200	0.732		9,826	1.734
	3,400	0.760		10,015	1.756
2	3,400	0.760	5	10,204	1.777
	3,589	0.785		10,393	1.796
	3,778	0.812		10,582	1.816
	3,967	0.849		10,761	1.838
	4,156	0.875		10,950	1.868
	4,345	0.903		11,139	1.907
	4,534	0.929		11,328	1.931
	4,723	0.954		11,517	1.960
	4,912	0.987		11,706	1.978
	5,101	1.008		11,895	2.004
	5,290	1.038		12,084	2.033
	5,479	1.066		12,273	2.047
3	5,668	1.094	6	14,100	2.223
	5,857	1.116		14,291	2.249
	6,046	1.144		14,481	2.271
	6,235	1.179		14,672	2.294
	6,424			14,863	2.315
	6,613	1.235		15,054	
	6,802	1.267		15,245	2.359
	6,991	1.294		15,436	2.377
	7,180	1.329		15,621	2.403
	7,369	1.364		15,812	2.427
	7,558	1.388		16,003	2.443
	7,747	1.420		16,194	2.471

Distance between Shot Points 1 and 2: 39,430 feet

* Distance from Shot Point 2 at southeast end of line

Line A continued

Soread	Distance*	Time	Spread	Distance	Time
7	18,400	2.787	10	26,300	3.637
	18,600	2.817		26,500	3.648
	18,800	2.835		26,700	3.659
	19,000	2.861		26,900	3.671
	19,200	2.867		27,100	3.685
	19,400	2.893		27,300	
	19,600	2.925		27,500	3.707
	19,800	2.952		27,700	3.719
	20,000	2.955		27,900	3.731
	20,200	2.986		28,100	3.743
	20,400	3.007		28,300	3.758
	20,600	3.031		28,500	3.769
8	20,800	3.035	11	28,700	3.780
	21,000	3.060		28,900	3.788
	21,200	3.075		29,100	3.799
	21,400	3.095		29,300	3.809
	21,600	3.115		29,500	3.819
	21,800	3.137		29,700	
	22,000	3.185		29,900	3.839
	22,200	3.198		30,100	3.849
	22,400	3.210		30,300	3.859
	22,600	3.225		30,500	3.869
	22,800	3.240		30,700	3.879
	23,000	3.255		30,900	3.889
9	23,900	3.516**			
	24,100	3.523			
	24,300	3.533			
	24,500	3.543			
	24,700	3.553			
	24,900				
	25,100	3.573			
	25,300	3.584			
	25,500	3.595			
	25,700	3.605			
	25,900	3.616			
	26,100	3.626			

* Distance from Shot Point 2

** This and following travel-times are not first breaks

SEISMIC DATA - LINE B

Spread	Distance*	Time	Spread	Distance	Time
1	50	0.067	4	5,230	1.022
	100	0.099		5,409	1.047
	200	0.152		5,588	1.077
	300	0.207		5,767	1.107
	400	0.252		5,948	1.137
	500			6,125	1.162
	600	0.334		6,304	
	700	0.358		6,483	1.208
	800	0.372		6,662	1.231
	900	0.393		6,841	1.260
	1,000	0.405		7,020	1.288
	1,100	0.423		7,199	1.306
2	1,300	0.452	5	10,600	1.758
	1,395	0.469		10,800	1.778
	1,492	0.486		11,000	1.811
	1,593	0.497		11,200	1.828
	1,691	0.516		11,400	1.852
	1,791	0.528		11,600	1.883
	1,890			11,800	
	1,990	0.558		12,000	1.913
	2,090	0.573		12,200	1.928
	2,190	0.587		12,400	1.933
	2,290	0.597		12,600	1.947
	2,390	0.611		12,800	1.966
3	2,580	0.653	6	13,000	1.970
	2,769	0.675		13,200	1.985
	2,958	0.696		13,400	2.000
	3,147	0.723		13,600	2.020
	3,336	0.746		13,800	2.030
	3,525	0.768		14,000	2.055
	3,714			14,200	
	3,903	0.816		14,400	2.095
	4,092	0.838		14,600	2.115
	4,281	0.856		14,800	2.125
	4,470	0.888		15,000	2.137
	4,659	0.905		15,200	2.150

* Distance from Shot Point 2 at northwest end of line

Line B continued

Spread	Distance*	Time	Spread	Distance**	Time
7	15,400	2.136	1	1,300 NW	0.419
	15,600	2.186		1,200	0.399
	15,800	2.205		1,100	0.398
	16,000	2.245		1,000	0.388
	16,200			900	0.369
	16,400			800	
	16,600			700	0.334
	16,800	2.285		600	0.322
	17,000	2.309		500	0.300
	17,200	2.304		400	0.258
	17,400	2.315		300	0.209
	17,600	2.315		200	0.160
			2	200 SE	0.157
				300	0.208
				400	0.264
				500	0.304
				600	0.309
				700	0.318
				800	
				900	0.343
				1,000	0.345
				1,100	0.352
				1,200	0.365
				1,300	0.371
			3	1,300	0.370
				1,500	0.393
				1,700	0.418
				1,900	0.441
				2,100	0.458
				2,300	0.495
				2,500	0.524
				2,700	0.555
				2,900	0.584
				3,100	0.618
				3,300	0.645
				3,500	0.674

Distance between Shot Points 2 and 3: approximately 11,900'

* Distance from Shot Point 2

** Distance from Shot Point 3

Line B continued

Spread	Distance*	Time	Spread	Distance*	Time
1	205	0.092	8,408	1.051	
	405	0.135	8,608	1.083	
	605	0.162	8,808	1.105	
	805	0.188	9,008	1.129	
	1,005	0.218			
	1,205	0.244			
	1,405	0.275			
	1,605	0.292			
	1,805	0.318			
	2,005	0.340			
	2,205	0.378			
	2,405	0.402			
2	2,608	0.414			
	2,808	0.446			
	3,008	0.471			
	3,208	0.496			
	3,408	0.526			
	3,608	0.553			
	3,808	0.576			
	4,008	0.606			
	4,208	0.626			
	4,408	0.647			
	4,608	0.662			
	4,808	0.685			
3	6,008	0.808			
	6,208	0.826			
	6,408	0.842			
	6,608	0.863			
	6,808	0.888			
	7,008				
	7,208	0.924			
	7,408	0.948			
	7,608	0.968			
	7,808	0.990			
	8,008	1.013			
	8,208	1.038			

Distance between Shot Points 2 and 4: approximately 21,208'

* Distance from Shot Point 4 at southeast end of line

SEISMIC DATA - LINE C

Spread	Distance*	Time
1	300	0.205
	500	0.298
	700	0.362
	900	0.402
	1,100	0.435
	1,300	0.471
	1,500	
	1,700	0.529
	1,900	0.563
	2,100	0.593
	2,300	0.628
	2,500	0.663
2	2,715	0.708
	2,915	0.763
	3,115	0.766
	3,315	0.798
	3,515	0.830
	3,715	0.861
	3,915	
	4,115	0.921
	4,300	0.945
	4,500	0.962
	4,700	0.996
	4,900	1.027
3	5,750	1.172
	5,945	1.201
	6,140	1.224
	6,335	1.253
	6,530	1.284
	6,725	
	6,920	1.330
	7,065	1.360
	7,260	1.382
	7,445	1.404
	7,640	1.441
	7,835	1.461

* Distance from Shot Point 2 at northeast end of line

Line C continued

Spread	Distance*	Time	Distance#	Time	Spread
4	8,035	1.500	3,377	0.539	2
	8,235	1.520	3,178	0.513	
	8,435	1.545	2,979	0.498	
	8,635	1.575	2,780	0.468	
	8,835	1.600	2,581	0.449	
	9,035	1.610	2,382	0.428	
	9,235		2,185		
	9,435	1.611	1,990	0.376	
	9,615	1.613	1,793	0.355	
	9,795	1.613	1,605	0.332	
	9,975	1.600	1,425	0.308	
	10,155	1.607	1,250	0.291	
			1,100	0.265	1
			1,000	0.249	
			900	0.230	
			800	0.213	
			700	0.204	
			600	0.191	
			500		
			400	0.137	
			300	0.117	
			200	0.079	
			100	0.038	
			25	0.015	
1**	51***	0.050	800##	0.359	1###
	151	0.137	900	0.358	
	251	0.191	1,000	0.364	
	351	0.232	1,100	0.372	
	451	0.279	1,200	0.374	
	551		1,300		
	651	0.298	1,400	0.374	
	751	0.286	1,500	0.374	
	851	0.283	1,600	0.349	
	951	0.277	1,700	0.354	
	1,051	0.270	1,800	0.349	
	1,151	0.276	1,900	0.349	

* Distance from Shot Point 2 at northeast end of line

Distance from Shot Point 5 at southwest end of line

** Same recording location as Spread 1 for Shot Point 5

*** Shot Point 5a 51 feet northeast of spread

Shot Point 5b 800 feet northeast of spread

Same recording location as Spread 1 for Shot Point 5

SEISMIC DATA - LINE D

Spread	Distance*	Time	Spread	Distance**	Time
1	1,300 NE	0.380	1	1,300 SW	0.242
	1,200	0.361		1,200	0.240
	1,100	0.350		1,100	0.234
	1,000	0.340		1,000	0.233
	900	0.329		900	0.229
	800			800	0.232
	700	0.322		700	0.231
	600	0.309		600	0.226
	500	0.294		500	0.213
	400	0.243		400	0.208
	300	0.198		300	0.170
	200	0.149		200	0.125
2	420 SW	0.266	2	200 NE	0.111
	520	0.297		300	0.164
	620	0.326		400	0.215
	720	0.359		490	0.250
	820	0.380		590	0.263
	920			689	0.269
	1,020	0.409		788	0.279
	1,120	0.420		885	0.294
	1,220	0.438		980	0.314
	1,320	0.454		1,078	0.320
	1,420	0.464		1,175	0.328
	1,520	0.465		1,270	0.338
3	1,520	0.477	3	1,280	0.334
	1,720	0.487		1,477	0.353
	1,920	0.500		1,674	0.374
	2,120	0.520		1,871	0.384
	2,320	0.544		2,068	0.406
	2,520	0.570		2,265	0.419
	2,720	0.584		2,462	0.449
	2,920	0.603		2,659	0.468
	3,120	0.613		2,856	0.489
	3,320	0.636		3,056	0.506
	3,520	0.660		3,256	0.521
	3,720	0.676		3,456	0.540

Distance between Shot Points 3 and 6a: 5,000 feet

* Distance from Shot Point 3

** Distance from Shot Point 6a

Line D continued

Spread	Distance*	Time
1	3,380	0.412
	3,577	0.435
	3,774	0.452
	3,971	0.461
	4,168	0.485
	4,365	0.505
	4,562	0.525
	4,759	0.541
	4,956	0.561
	5,156	0.580
	5,356	0.591
	5,556	0.608

Distance between Shot Points 6 and 6a: 2,100 feet

Distance between Shot Points 3 and 6: 7,100 feet

* Distance from Shot Point 6 at southwest end of line

PUBLISHED GEOLOGICAL INFORMATION RELEVANT TO
THE SAN JACINTO GROUND WATER BASIN

A brief abstract or comments follow some of the references. The references are presented in chronological order
1857 Blake, W. P., Geological report (Williamson's reconnaissance in California) U. S. Pacific railroad exploration: U. S. 33rd Cong., 2d sess., S. Ex. Doc. 78 and H. Ex. Doc. 91, vol. 5, pt. 2, 370 p.

Map 4, covering most of southern California, is at a scale of 1:1,500,000.

1871 Guillemin-Tarayre, E., Description des anciennes possessions mexicaines du nord: Mission Scientifique au Mexique et dans l' Amerique Centrale, Geologie pt. 2, 216 P.

Plate 15 covers southern California west of approximately 116° 50' west longitude at a scale of 1:1,000,000.

1886 Hanks, H. G., San Diego County: California Min. Bur. 6th Ann. Rept. pt. 1, pp. 80-90.

The map covers the southeastern half of the San Jacinto ground water basin at a scale of 1:375,000.

1893 Fairbanks, H. W., Geology of San Diego County; also portions of Orange and San Bernardino Counties: California Min. Bur. 11th Ann. Rept., pp. 76-120.

The map covers almost all of the San Jacinto ground water basin at a scale of 1:375,000.

1899 The Riverside PRESS AND HORTICULTURIST, December 30th.

A newspaper article describes the San Jacinto earth-

quake of December 25, 1899. The south walls of brick buildings "invariably went down, most of them falling outward."

1900 Claypole, E. W., The earthquake of San Jacinto, December 25, 1899; Am. Geologist, vol. 25, pp. 106-108.

In Hemet, almost all brick buildings were severely damaged and only two chimneys remained standing. Six people were killed and eight injured at Saboba. Ten miles southeast of San Jacinto there were many fresh surface cracks and it is possible that the earthquake centered near here. Some damage was done to Riverside and the shock was distinctly felt at San Diego and at Saligman, Arizona. Aftershocks occurred through May of 1900.

1907 Danes, J. V., Das Erdbeben von San Jacinto am 25 December 1899; Mitteilungen der K. K. Geogr. Gesellschaft in Wien, Heft 6-7, pp. 339-347.

A report of the San Jacinto earthquake of December 25, 1899.

1908 Lawson, A. C., and others. The California earthquake of April 18, 1906; Carnegie Inst. Wash. Pub. 87, vol. 1, 451 p.

This report of an earthquake investigation committee includes a reconnaissance of the San Andreas fault system. It shows the San Jacinto fault as a continuous break from the San Jacinto Valley to the Borrego Valley.

1908 Hess, F. L., The Magnesite deposits of California;

U. S. Geological Survey Bull. 355, 67 p.

The bulletin contains a brief description of the serpentine in the vicinity of the magnesite mine south of Hemet airport.

1912 Gale, Hoyt S., Late developments of magnesite deposits in California and Nevada; U. S. Geological Survey Bull. 540, pp. 483-520.

Gale's article contains more information on the magnesite mine south of Hemet airport. Figure 54 is a geological map at a scale of 1:13,500.

1915 Beal, Carl H., The earthquake in the Imperial Valley, California, June 22, 1915; Bulletin of the Seismological Soc. of Am., vol. 5, pp. 130-149.

Beal maps the San Jacinto fault as a single fault line passing north of the town of San Jacinto, apparently at the southwest base of the mountains north of San Jacinto.

1918 Townley, Sidney D., The San Jacinto earthquake of April 21, 1918; Bulletin of the Seismological Soc. of Am., vol. 8, pp. 44-62.

The article contains several pictures of the damage caused by this earthquake - and there was much damage. The quake was felt over all of southern California and western Arizona. Fortunately the quake occurred on a Sunday afternoon so few people were in the business districts. Many injuries resulted but no deaths. The concrete road between Hemet and San Jacinto was cracked in thirteen places and

the concrete road running northwesterly from San Jacinto was seriously cracked and buckled. Many live limbs were shaken from trees. A number of landslides occurred in the San Jacinto mountains, one swept a car off the road. The ground was cracked in several places throughout the valley as were irrigation canals.

1918 Rolfe, Frank and A. M. Strong, The earthquake of April 21, 1918, in the San Jacinto Mountains; Bulletin of the Seismological Soc. of Am., vol. 8, pp. 63-67.

A description of the earthquake effects on the area to the south and east of San Jacinto Valley is given.

1918 Arnold, Ralph, Topography and fault system of the region of the San Jacinto earthquake; Bulletin of the Seismological So. of Am., vol. 8, pp. 68-73.

The main branch of the San Jacinto fault zone is located as passing through Hog Lake, the Blackburn ranch, by the northeastern side of Park Hill and under the town of San Jacinto.

1918 The Los Angeles TIMES, April 23, 1918.

A newspaper article describes the San Jacinto earthquake of April 21, 1918. "There were nine separate temblors over a period of thirty hours, beginning Sunday at 3:32 o'clock p. m."

1919 Waring, G. A., Ground water in the San Jacinto and Temecula basins, California; U.S. Geological Survey Water Supply Paper 429.

Waring's water supply paper represents a detailed starting point of recorded information on the ground water of these two basins. It describes water use, quality, level, origin and fluctuation. The likelihood of overdraft is pointed out and many well logs are presented.

1920 Hill, R. T., The rifts of Southern California; Bulletin of the Seismological Soc. of Am., vol. 10, pp. 146-149.

Little new information is presented. Hill expresses his feeling that too much concern is given to the destructive effects of earthquakes.

1921 Frick, Childs, Extinct vertebrate faunas of the Badlands of Bautista Creek and San Timoteo Canyon, southern California; Univ. Calif. Pub., Bull. Dept. Geol. Sci., vol. 12, no. 5, pp. 277-424.

A paleontological dating of the sediments of the badlands on the edges of the San Jacinto ground water basin is presented.

1924 Woodford, A. O., The Catalina metamorphic facies of the Franciscan series; Calif. Univ. Dept. Geol. Sci. Bull., vol. 15, no. 3, pp. 49-68.

Figure 1 of Woodford's article is a geological map at a scale of 1:1,500,000 that includes portions of San Diego, Orange, and Riverside counties. The northeastern corner of this map includes Winchester, Romoland, Homeland, and the Menifee areas. Since the publication of this article, more detailed mapping of these areas has been pub-

lished.

1926 English, W. A., Geology and oil resources of the Puente Hills region, southern California; U.S. Geological Survey Bull. 768, 110 p.

In this bulletin English names the rather stable geologic area between the San Jacinto and the Elsinore fault zones the "Perris fault block." This is about the only item in the bulletin that is pertinent to the San Jacinto basin.

1928 Hill, R. T., Southern California geology and Los Angeles earthquakes; Published by Southern Calif. Acad. Sci., Los Angeles, 232 p.

Hill states that from 1780 to 1928 there were 170 reported shocks in southern California; 92 on the San Jacinto rift, 16 on the San Andreas rift, 16 on the Elsinore rift, 14 near Inglewood, 2 near Los Angeles city and 30 shocks from distant localities.

1928 Post, W. S., Santa Ana investigation, flood control and conservation; California Div. Engr. and Irrigation Bull. 19, 367 p.

Map 14, at a scale of 1:250,000, includes most of the San Jacinto ground water basin.

1931 Fraser, D. M., Geology of San Jacinto quadrangle south of San Geronio Pass, California; Mining in Calif. (Calif. Jour. of Mining and Geology,) vol. 27, pp. 494-540.

Through somewhat reconnaissance in coverage, this article, a condensation of Fraser's doctoral dissertation contains many observation of interest to any geological study in the area. His map is at a scale of 1:125,000 and extends as far west as 117° west longitude, approximately Sanderson street.

1932 Sampson, R. J., Economic mineral deposits of the San Jacinto quadrangle; Mining in Calif. (Calif. Jour. of Mining and Geology,) vol. 28, pp. 3-11.

The map scale is 1:125,000 and is of no interest to ground water studies.

1933 Murdoch, Joseph, Andalusite in pegmatite; Am. Mineralogist, vol. 21, pp. 68-69.

Murdoch gives a discription of the pegmatites associated with the serpentines of the magnesite mine area south of Hemet airport.

1934 Eckis, R., South Coastal Basin investigation; Geology and ground water storage capacity of valley fill; Calif. Div. Water Resources Bull. 45, 279 p.

Though this bulletin does not cover the San Jacinto ground water basin, Bean's estimate of the specific yield in the San Jacinto - Hemet area (Bean, 1955) is based on results of this bulletin.

1935 Sampson, R. J., Mineral resources of a portion of the Perris Block, Riverside county, Calif.; Calif. Jour. of Mines and Geology, vol. 31, pp. 507-521.

Though historically interesting, Sampson's article is of no interest to ground water studies.

1935 Dudley, P. H., Geology of a portion of the Perris Block, southern California; Calif. Jour. of Mines and Geology, vol. 31, pp. 487-506.

The major emphasis of Dudley's article is the igneous and metamorphic rocks, their petrology and the sequence of their emplacement.

1936 Dudley, P. H., Physiographic history of a portion of the Perris Block, southern California; Jour. Geol., vol. 44, pp. 358-378.

In order to understand the more recent geological history of the Perris Block, this article examines the erosional and fault land forms. It is an assistance in understanding the bedrock features below the valley sediments.

1937 Axelrod, D. I., A Pliocene flora from the Mt. Eden beds, southern California; Carnegie Inst. Washington, Pub. 476, pp. 125-184..

The badland sediments north of the San Jacinto valley are dated with the aid of plant fossils.

1939 Henderson, L. H., Detailed geological mapping and fault studies of the San Jacinto tunnel line and vicinity; Jour. Geol., vol. 47, pp. 314-324.

Over twenty faults, parallel or subparallel to the San Jacinto fault zone, are mapped and their effect on

the San Jacinto tunnel is reported. These faults produced much water and caused severe problems during the driving of the tunnel.

1939 Osborn, E. F., Structural petrology of the Val Verde tonalite, southern California; Geol. Soc. America Bull., vol. 50, pp. 921-950.

The basement rock west of a portion of the Perris sub-basin of the San Jacinto ground water basin is examined in this article.

1939 Webb, Robert W., Evidence of the age of a crystalline limestone in southern California; Jour. Geol., vol. 47, pp. 198-201.

Webb found Carboniferous (Mississippian) fossils in the limestone interbedded with the schists north and south of Domenigoni valley and thus helped date the older metamorphic rocks around and below part of the San Jacinto basin.

1948 Larsen, E. S., Jr., Batholith and associated rocks of Corona, Elsinore, and San Luis Rey quadrangles, southern California; Geol. Soc. America Mem. 29, 182 p.

Most of the information of Larsen's memoir is contained in his 1951 Calif. Div. of Mines bulletin.

1949 Sprotte, E. C., The San Andreas and San Jacinto fault zones; Sigma Gamma Epsilon, The Compass, vol. 26, pp. 315-319.

1950 Axelrod, D. I. Further studies of the Mt. Eden flora,

southern California; Carnegie Inst. Washington, Pub. 590, pp. 73-118.

1951 Larsen, E. S., Jr., Crystalline rocks of the Corona, Elsinore, and San Luis Rey Quadrangles, southern California; Calif. Div. of Mines bulletin 159, pp. 7-50.

The petrology and relative age of the basement rocks are discussed in detail but little information is presented about the faults and almost no information about the water bearing sediments. Larsen's map is at a scale of 1:125,000 and indicates the type of exposed crystalline rocks in and around the portion of the San Jacinto ground water basin that is west of 117° west longitude (approximately Sanderson street.) Larsen's work can be of assistance in obtaining estimates of the relative permeabilities of the crystalline rocks.

1954 Jahns, R. H., Geology of the Peninsular range province, southern California and Baja California; Calif. Div. of Mines Bull. 170, chapter II, pp. 29-52.

The San Jacinto ground water basin is in the northern part of the Peninsular range. Jahns' article gives a clear understanding of the geological framework of which the San Jacinto basin is a small part.

1954 Jahns, R. H., Northern part of the Peninsular range province; Calif. Div. of Mines Bull. 170, geologic guide No. 5, 59 p.

This guide book presents a tour of the geology sur-

rounding, but not including, the San Jacinto ground water basin. It is accompanied by several geologic maps.

1954 Gray, Cliffton H., Geology of the Corona-Elsinore-Murrieta area, Riverside county; map sheet No. 21, Calif. Div. of Mines Bull. 170.

The includes the southwestern portion of the San Jacinto ground water basin. This portion of the map is based on Dudley (1935 and 1936) and Larsen (1948) and little or no new information is presented.

1955 Kundert, C. J., Santa Ana Sheet; Geological Map of California, Calif. Div. of Mines.

In the area of the San Jacinto ground water basin this map is based on Larsen (1951) and Fraser (1931) and no new information is presented. The scale is 1:250,000. The map has been reissued in 1965 and contains more detailed information. See 1965, Rogers.

1955 Bean, Robert T., Geology of San Jacinto and Elsinore basins, appendix B, Santa Ana river investigation; bulletin No. 15, Calif. State Water Resources Board, 88 p.

Bean's report covers in detail the ground water geology and geology of the water bearing sediments. The areal geology of the crystalline rocks is based on previous work by other geologists.

1959 Engel, Rene, Geology and mineral deposits of the Lake Elsinore quadrangle, California; Calif. Div. of Mines Bull. 146, 154 p.

Bulletin 146 just touches the southwestern corner of the San Jacinto ground water basin near Railroad canyon reservoir. In that area the igneous and metamorphic rocks are mapped in somewhat more detail than by Larsen (1951.) Engel's Santa Ana formation is called Bedford Canyon formation by Larsen and most other geologists. The map scale is 1:62,500.

1962 Proctor, R. J., Geologic features of a section across the Casa Loma fault, exposed in an aqueduct trench near San Jacinto, California; Geological Soc. Am. Bull., vol. 73, pp. 1293-1296.

Evidence of very recent movement of the Casa Loma fault is reported.

1964 Eaton, G. N., Martin, and M.A. Murphy, Application of gravity measurements to some problems in engineering geology; Engineering Geology, vol. 1, no. 2, pp. 6-21.

Northeast of Perris a gravity survey was performed. Knowing the depth to basement rock from test hole information and knowing the density of basement rock and the grain density of the sediments, it was possible to estimate the porosity of the sediments. A porosity of 36 to 40 percent was indicated.

1965 Rogers, Thomas H., Santa Ana Sheet; Geologic Map of California, Calif. Div. of Mines.

Rogers compiled this geologic map and did some of the mapping. The San Jacinto basin portion of the map is

based primarily on Bean's 1955 work.

1967 Fett, J.D., D.H. Hamilton, and F.A. Fleming, continuing surface displacements along the Casa Loma and San Jacinto faults in San Jacinto Valley, Riverside County, California; Engineering Geology, vol. 4, no. 1, pp 22-32

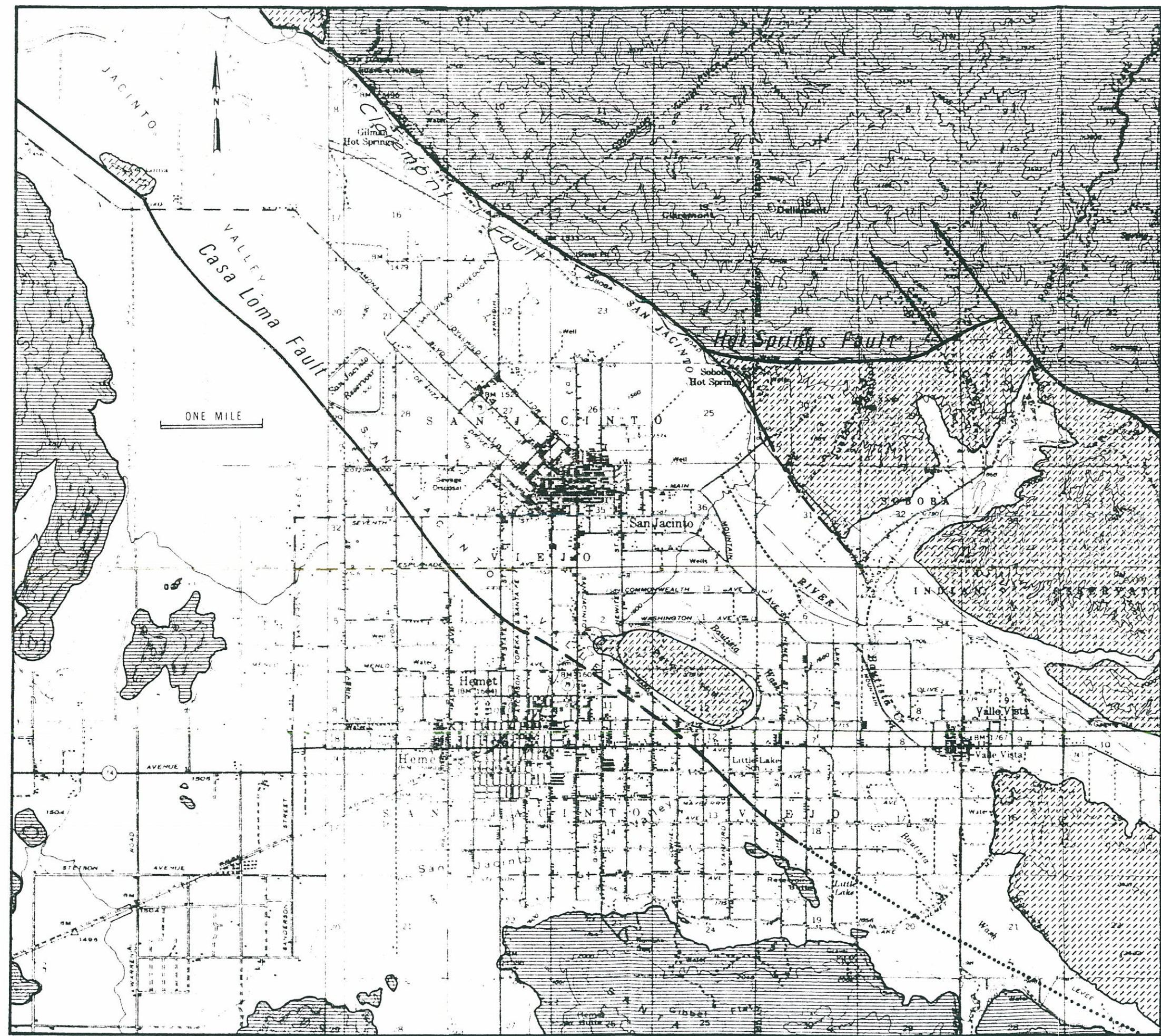
Displacement and pipeline and road fracturing along these faults are reported. The city of San Jacinto subsided more than a foot in the period 1932-1964. More recent work establishes the cause of current subsidence to be ground water withdrawal (Fett and Hamilton, in preparation and to be submitted to Engineering Geology.)

1967 Sharp, Robert V., San Jacinto fault zone in the Peninsular Ranges of Southern California; Bull. Geol. Soc. Am., vol. 78, no. 6, pp 705-730.

This paper is based on Sharp's doctoral dissertation. The San Jacinto fault zone and adjacent geology have been investigated from the southeast end of San Jacinto valley to the Borrego Valley area. Fifteen miles of right-lateral displacement has occurred as well as one to two miles of vertical displacement, the northeast side dropping with relation to the southwest side.

1966 AXELSON, DORRIS E. The Pleistocene to Recent Fluvial
of the Central California; University of California
Publication in Geological Sciences, Vol. 6, No. 1.

FIGURE 2



Geologic Units

LATE QUATERNARY

 Alluvium, Alluvial Soil, & Terrace Deposits

EARLY QUATERNARY

— LATE TERTIARY

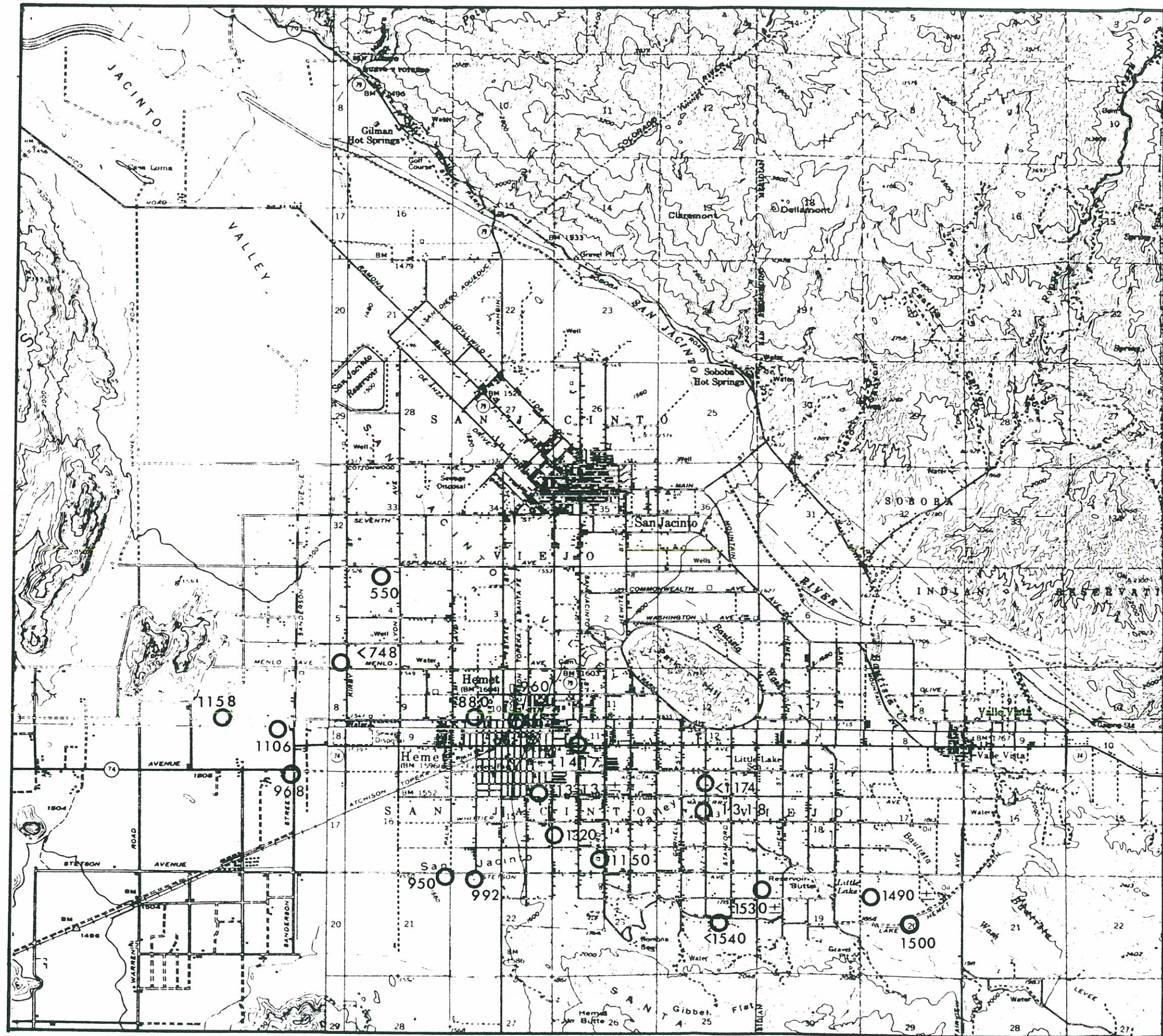
 Non-Marine Sedimentary Rocks

PRE-TERTIARY

 Crystalline Igneous & Metamorphic Rocks

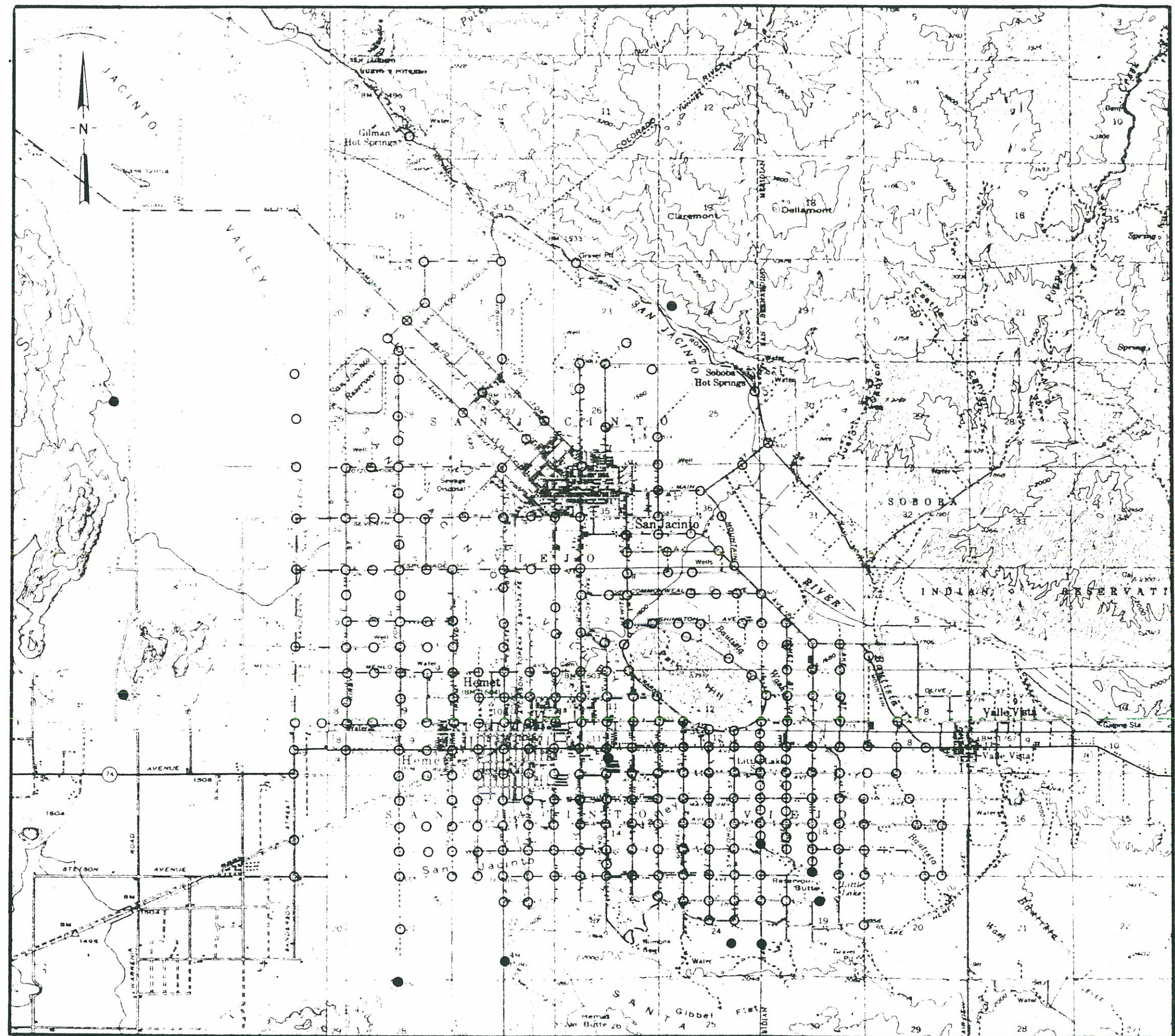
*Brief Geologic Map
of the
San Jacinto Valley Area*

FIGURE 3



*Bedrock Elevations
From Well Log Data*

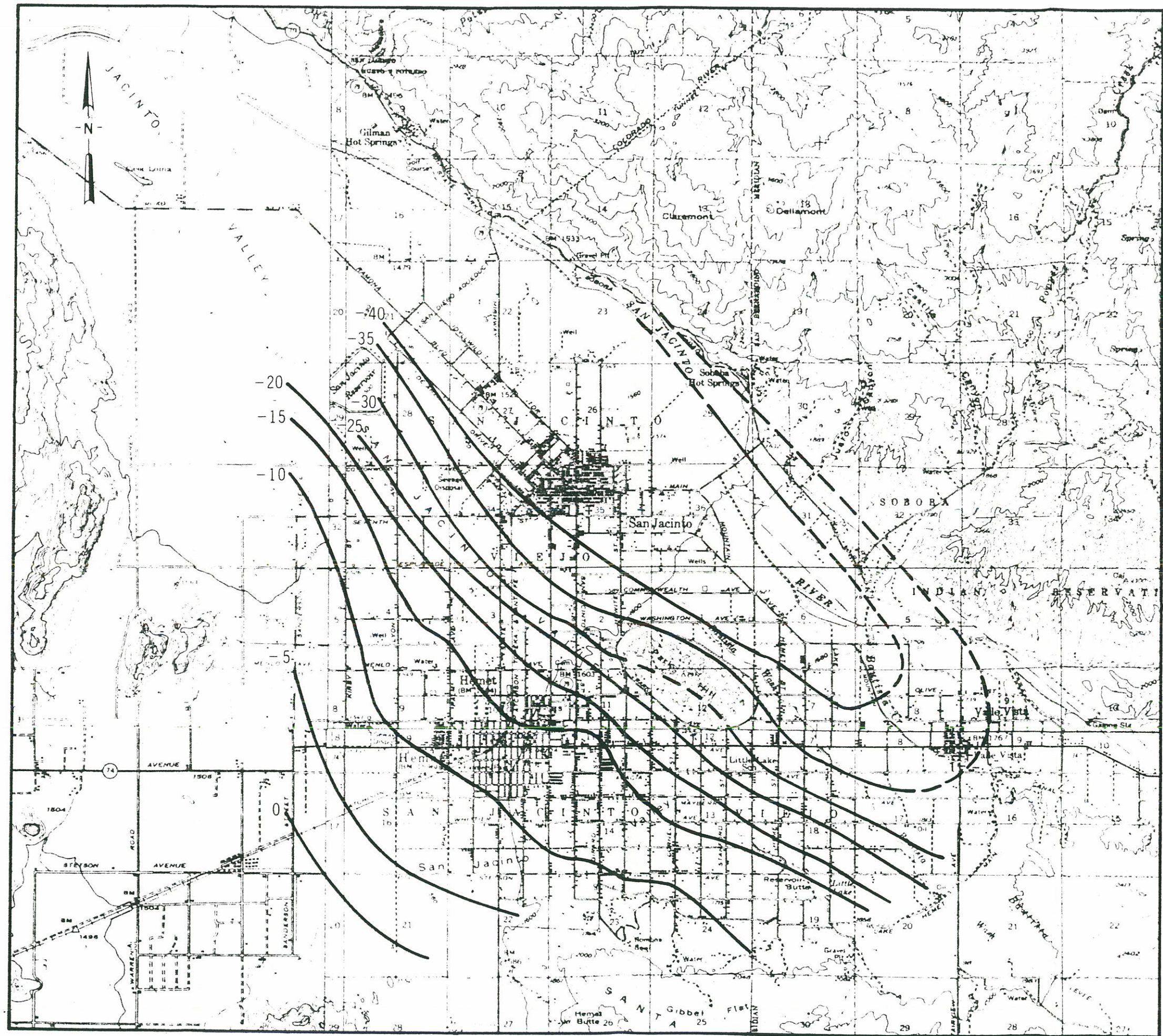
FIGURE 4



*Location of
Gravity Stations*

- Gravity Station On Bedrock
- Gravity Station On Sediments

FIGURE 5

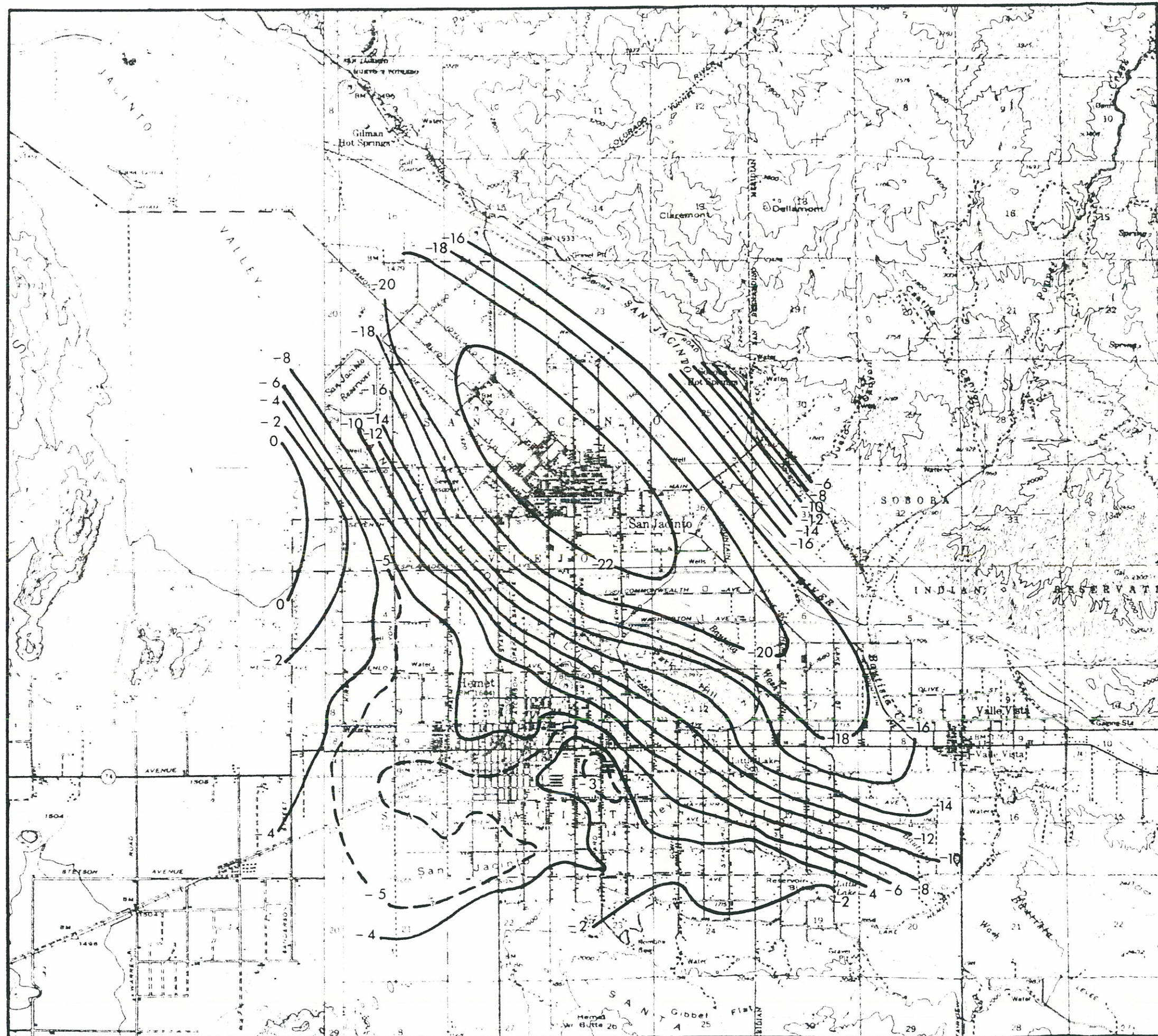


*Bouguer Gravity
Anomaly Map*

5 Milligal Contour Interval

Arbitrary Datum

FIGURE 6

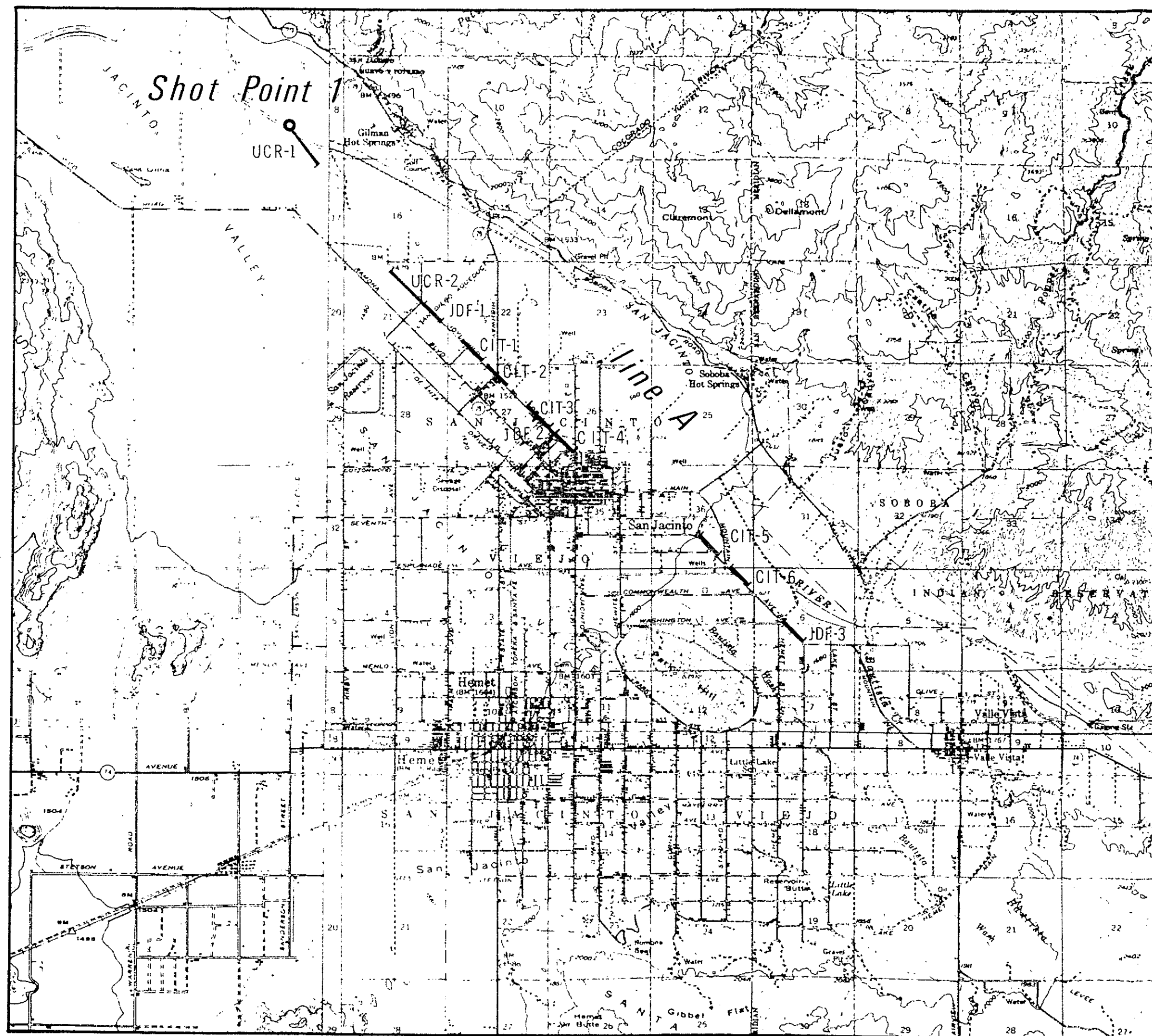


*Bouguer Gravity
Anomaly With
Regional Removed*

2 Milligal Contour Interval

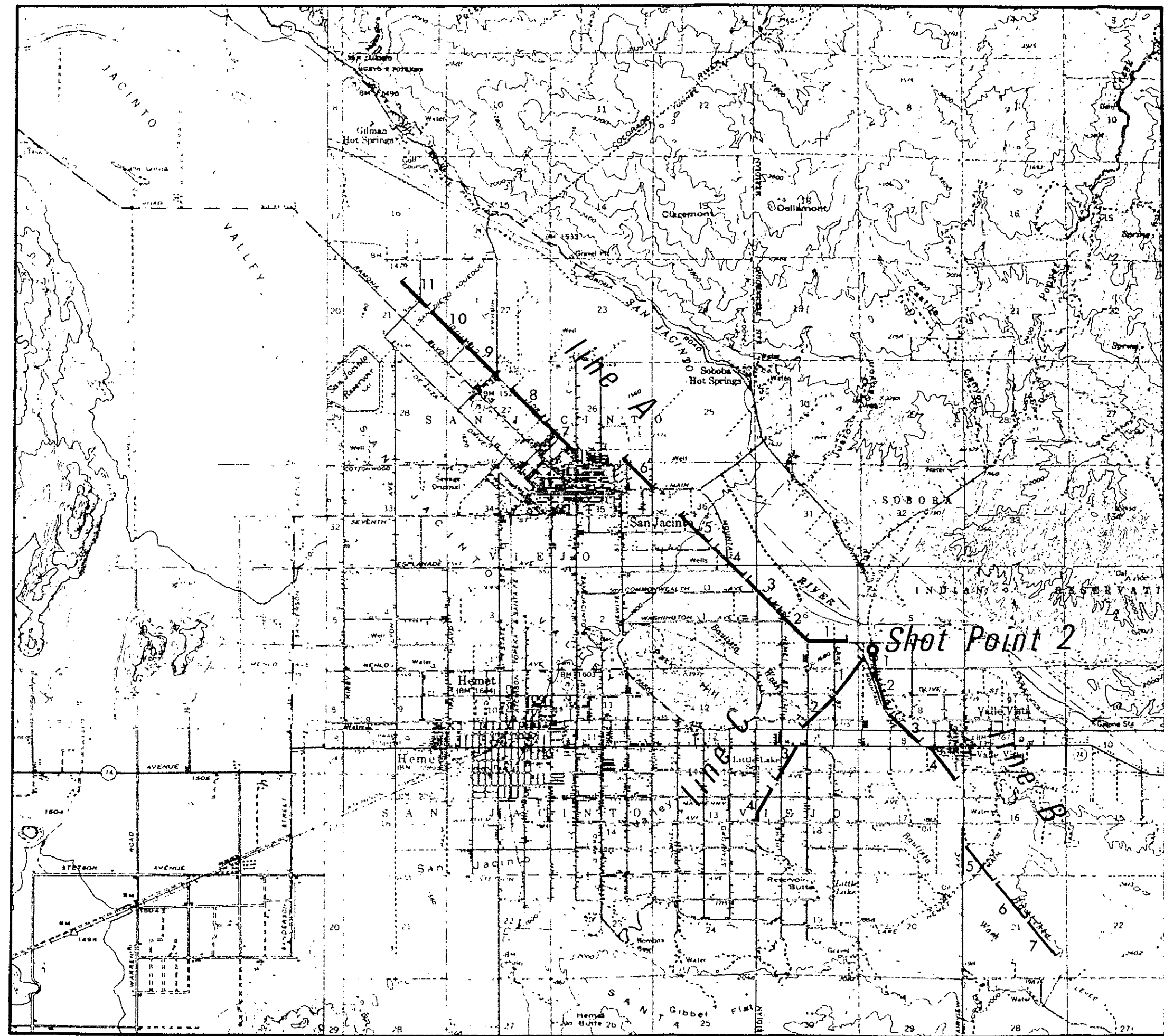
Arbitrary Datum

FIGURE 7



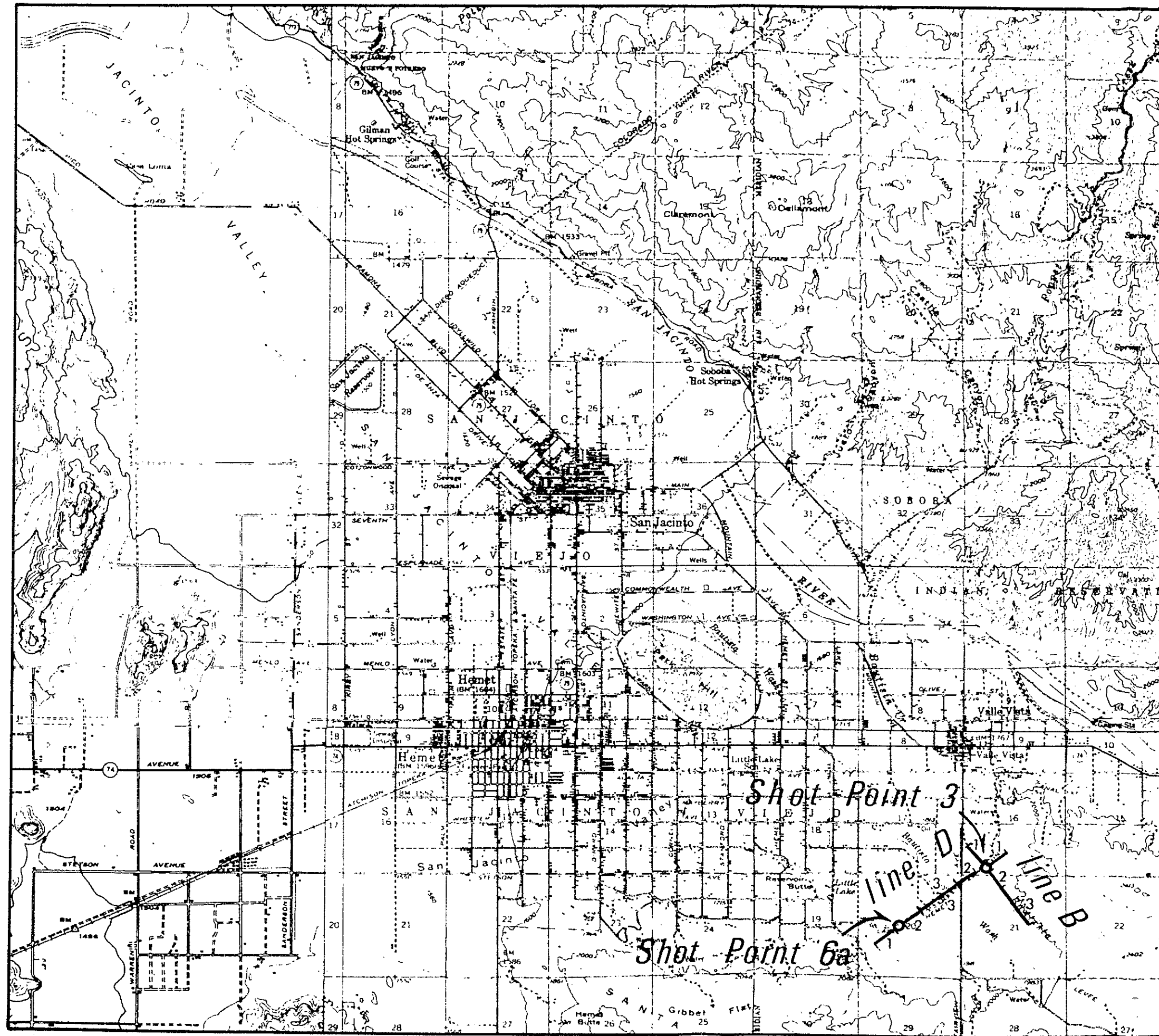
Recording Locations
for
Shot Point 1

FIGURE 8



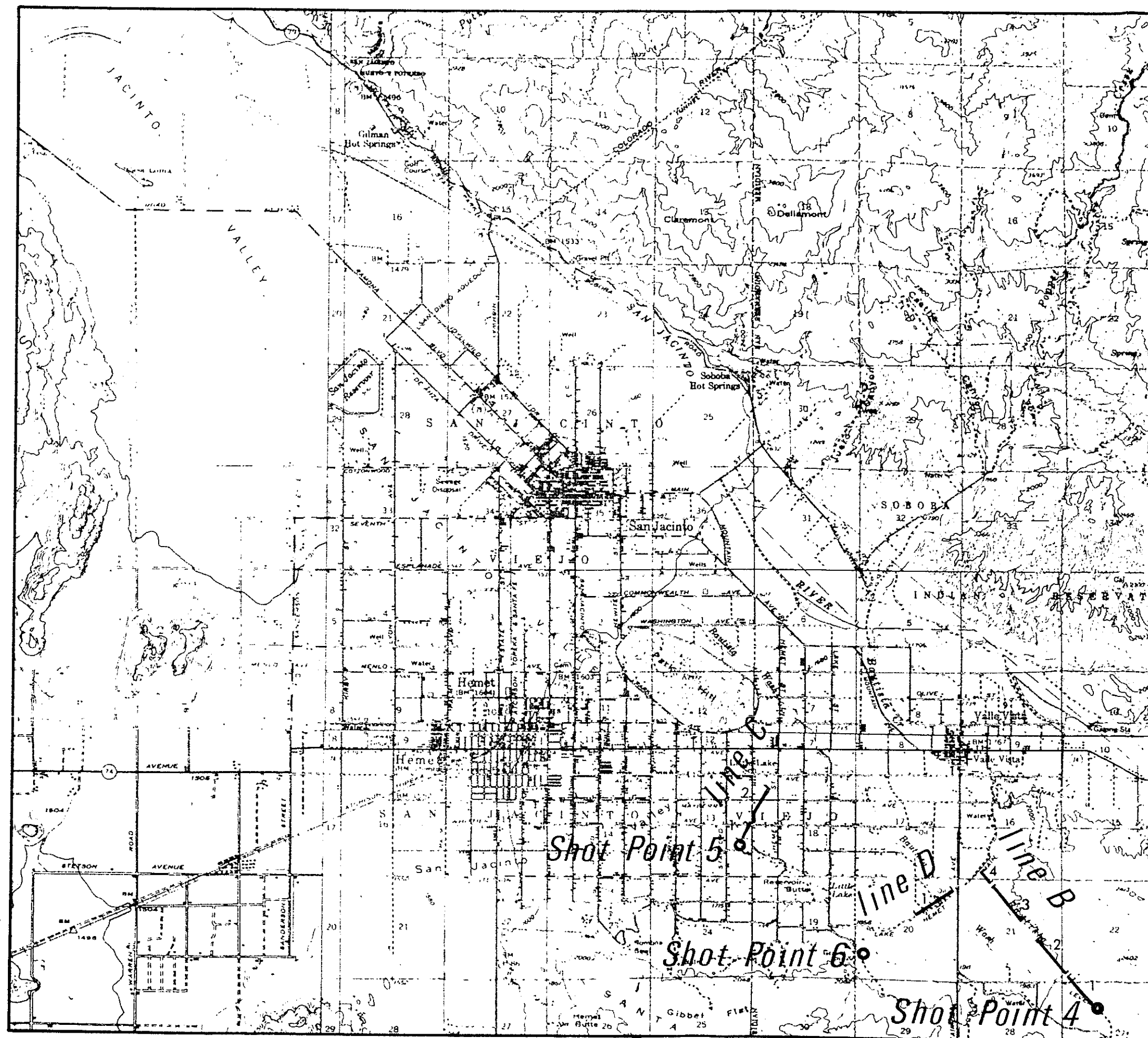
Recording Locations
for
Shot Point 2

FIGURE 9

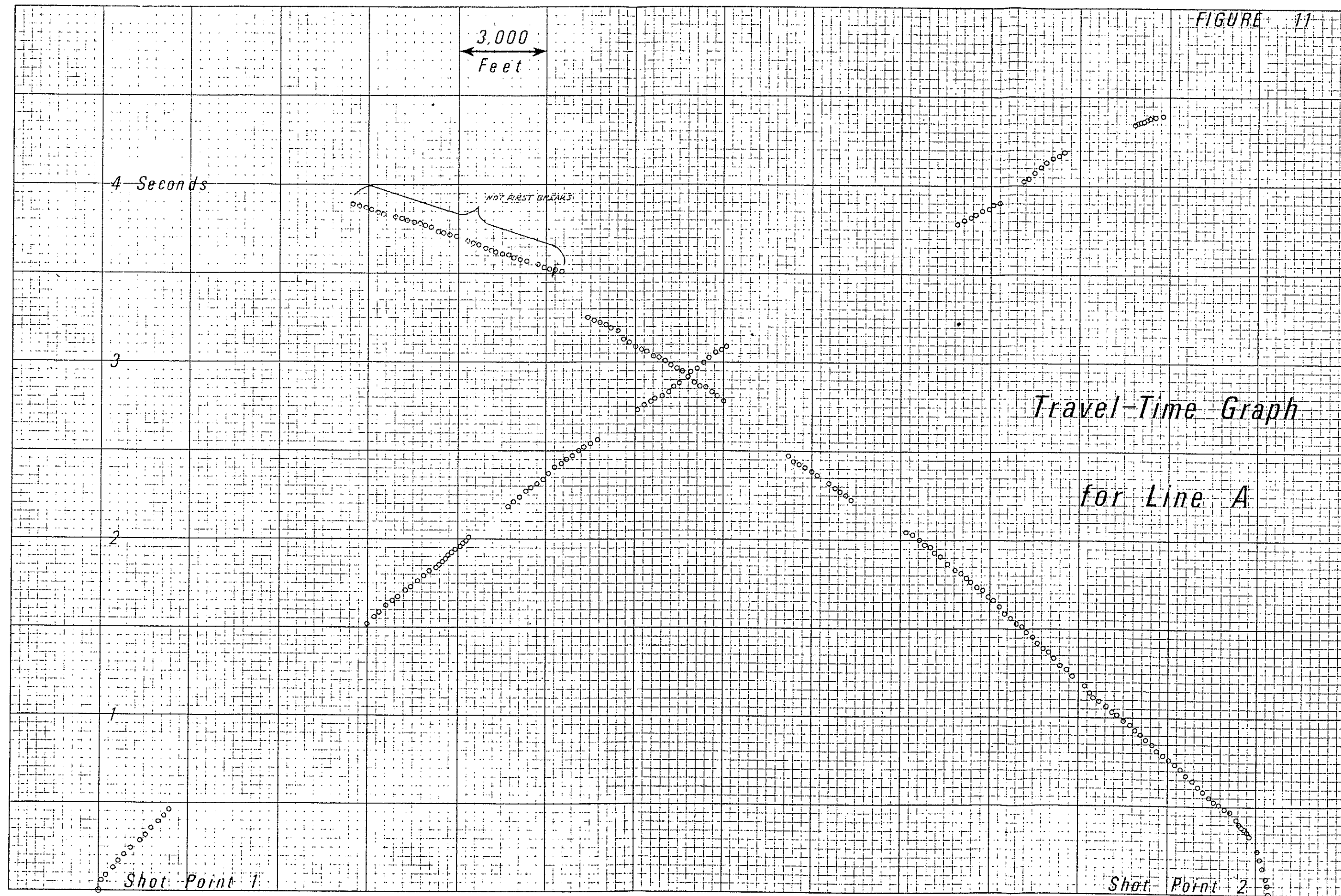


Recording Locations
for
Shot Points 3 & 6a

FIGURE 10



*Recording Locations
for
Shot Points 4, 5, & 6*



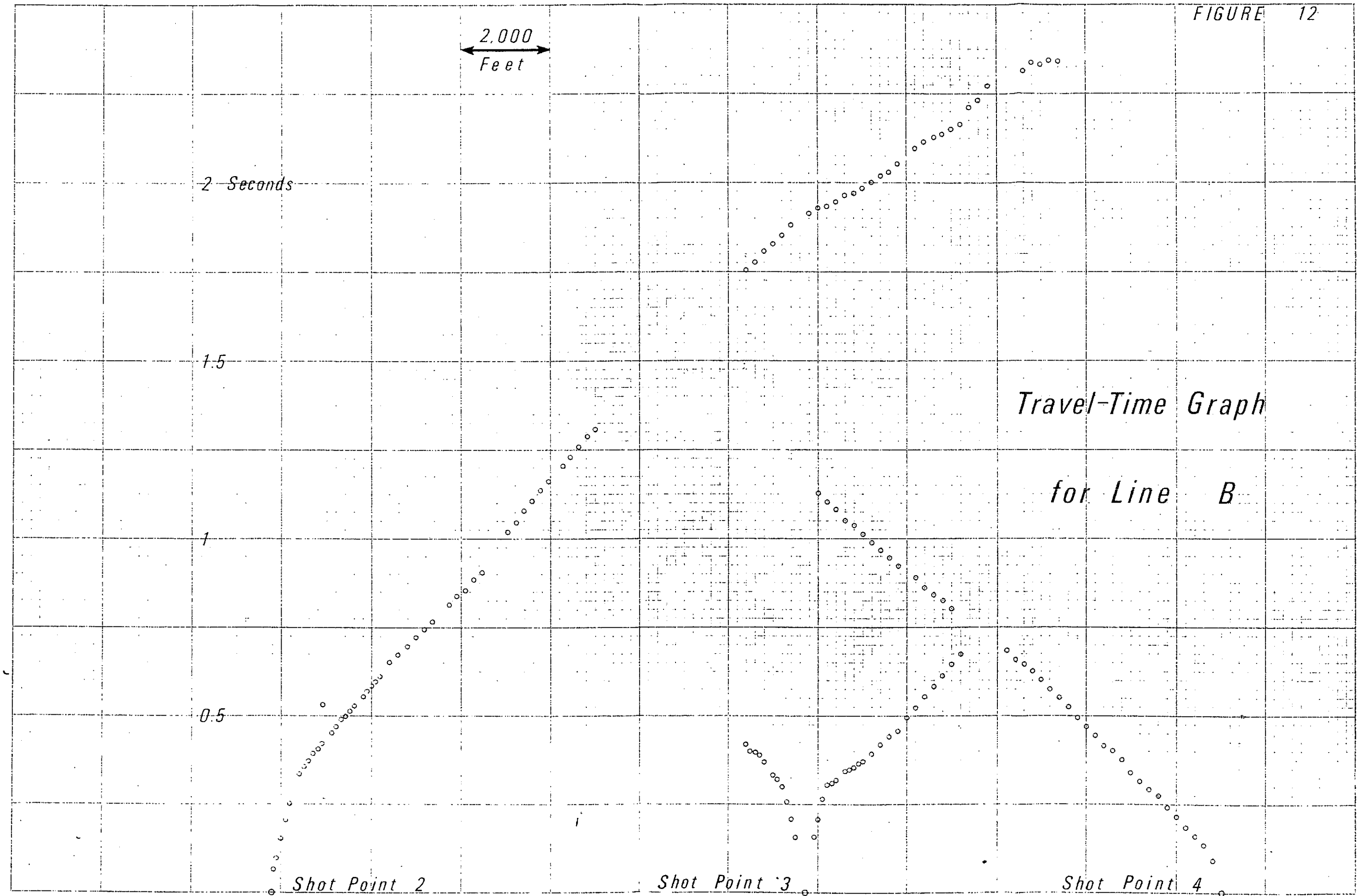
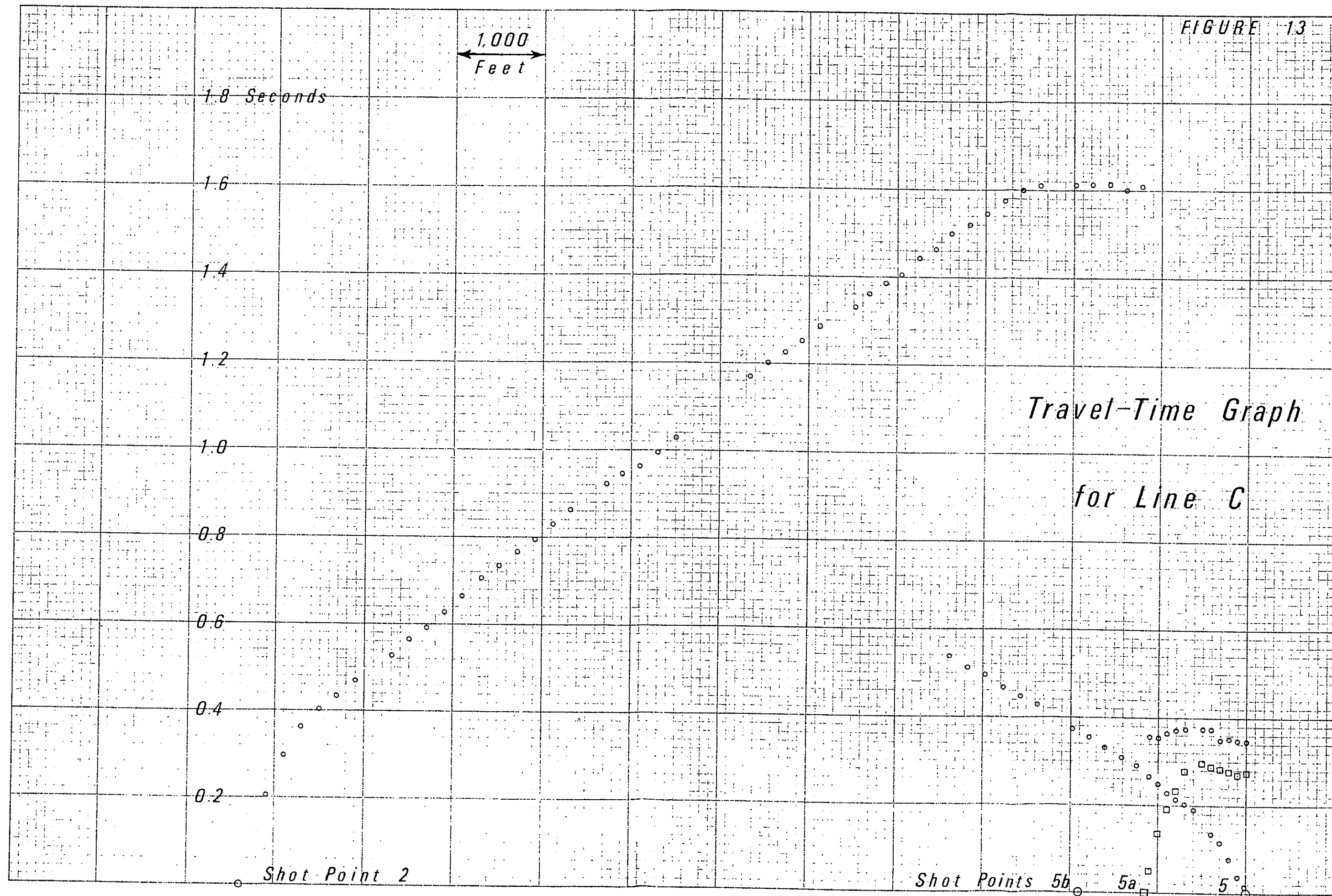


FIGURE 13



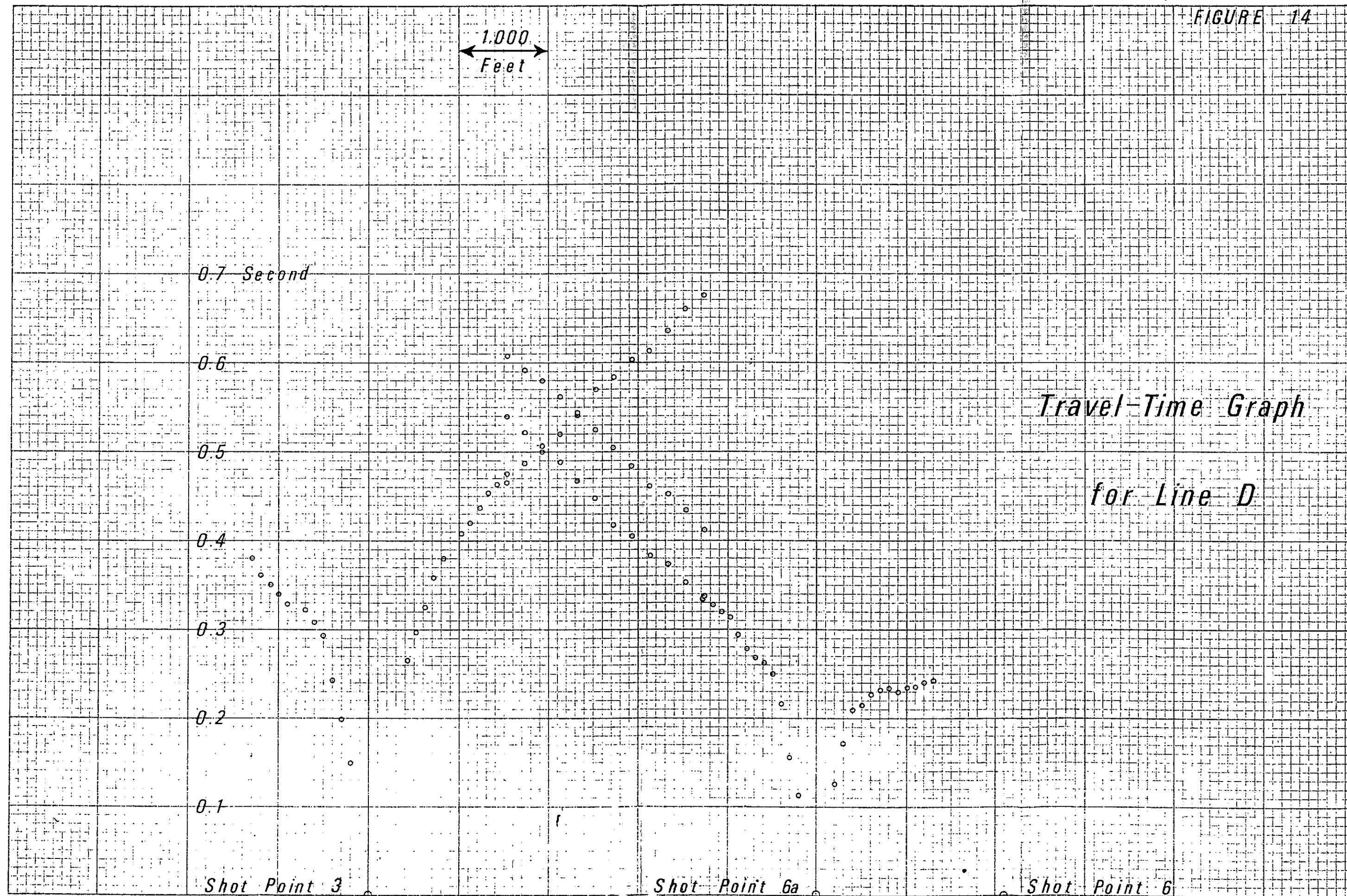
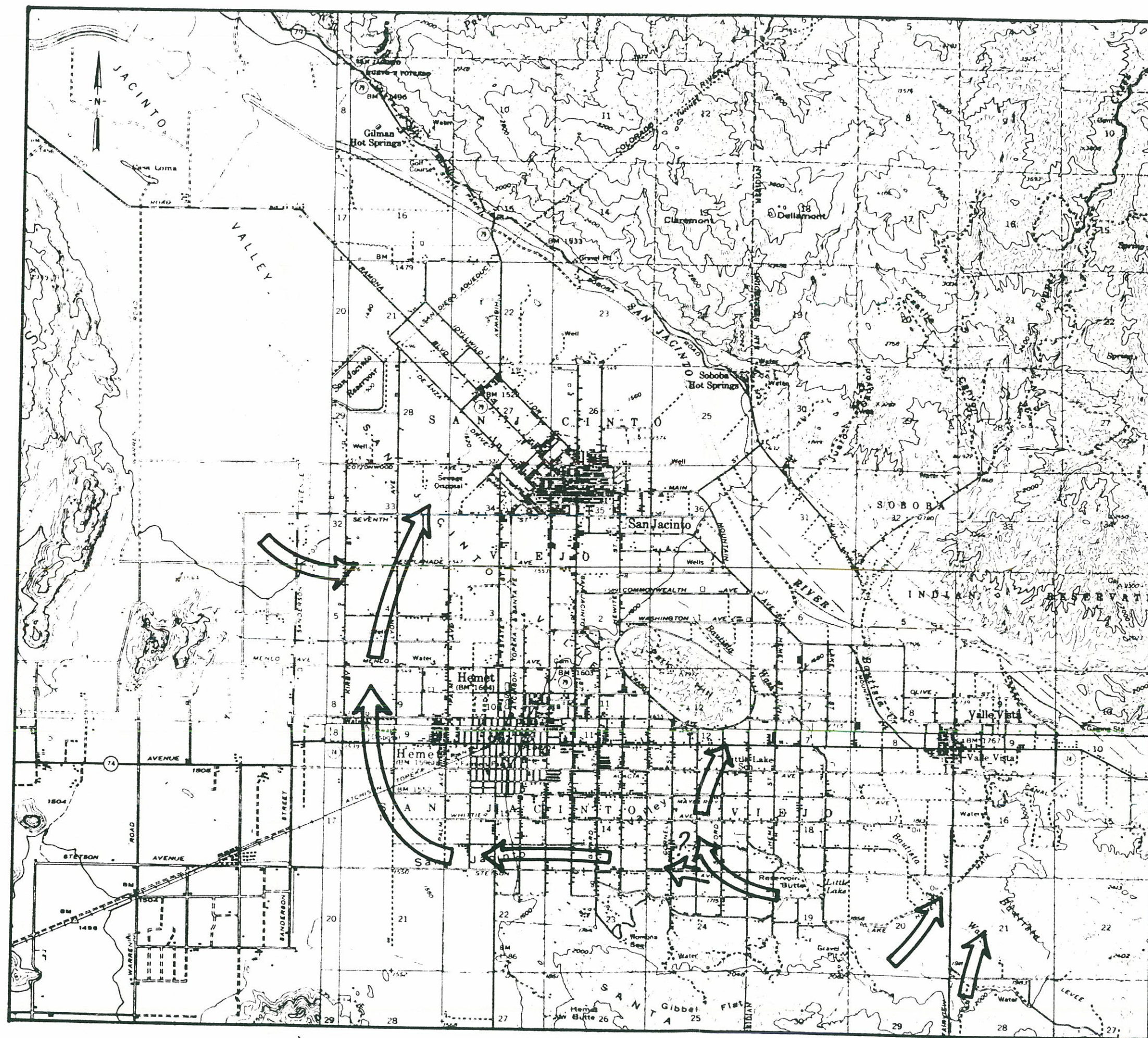
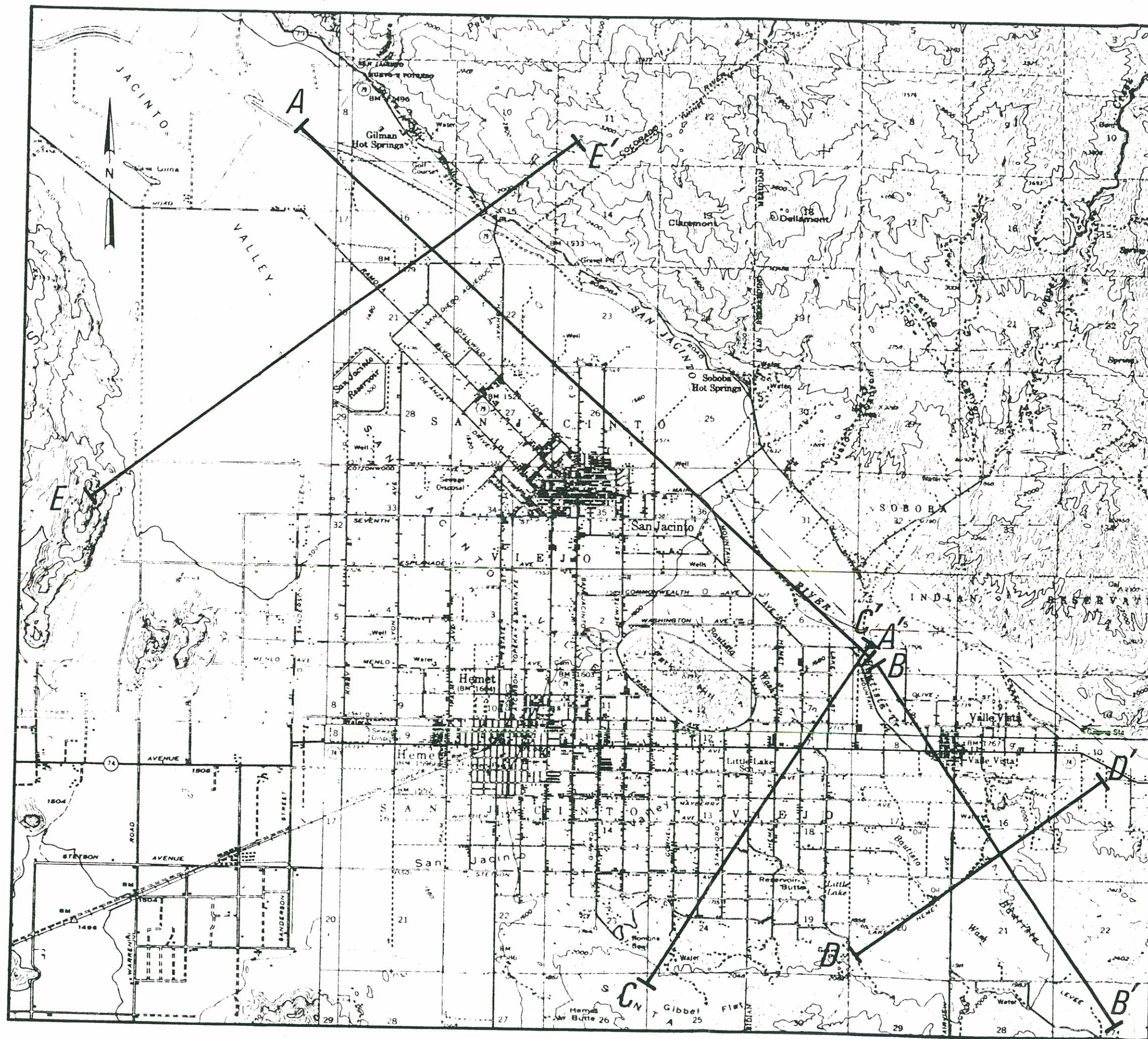


FIGURE 15



*Drainage Patterns
on the
Buried Bedrock Surface*

FIGURE 16



*Location of
Geologic Sections*