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Hydrogeologic Investigation  
Of the Mound Ground Water Basin  
For the City of San Buenaventura, Calif

**G E O T E C H N I C A L   C O N S U L T A N T S ,   I N C .**

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## INTRODUCTION

### GENERAL

This report presents the findings of our hydrogeologic investigation of the Mound Ground Water Basin for the purpose of locating well sites for additional groundwater supplies for the City of San Buenaventura. The Mound Basin encompasses the City of San Buenaventura and areas northwest, east and south of the city boundaries. See Plate 1 - Location Map.

### PURPOSE

The purpose of this investigation was to determine the feasibility of locating water wells northerly of the Santa Paula Freeway to serve the proposed water storage facilities to be constructed in the vicinity of Loma Vista Road and Victoria Avenue in the City. The immediate ground water demand is approximately 2400 gallons per minute.

### SCOPE

This hydrogeologic investigation represents Part A of Phase I of our exploration program as outlined in our letter of proposal to the City of San Buenaventura dated April 6, 1972. This investigation was conducted to delineate an exploratory drill hole or water well location and alternate sites within the Mound Basin with specifications and cost estimates.

Work performed for this investigation included:

1. Research of available geologic and hydrologic literature.
2. Acquisition of available well logs and electric logs of water wells.

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3. Acquisition of available well logs and electric logs of wildcat oil wells.
4. Correlation of boring logs and electric logs.
5. Acquisition of available water quality and water level data.
6. Hydrogeologic analysis to provide recommendations for proposed well locations, cost estimates for recommended wells, and well specifications.
7. Preparation of this report presenting findings, conclusions, and recommendations.

It should be noted that the initial scope of work as outlined in our letter of proposal necessarily had to be altered in order to complete this study. The original scope was based on the premise that much readily accessible and up-to-date data had been compiled in conjunction with the joint water resources management study begun in 1969 by the Department of Water Resources and Ventura County Flood Control District. For our study we found that these data did not totally include the Mound Basin and also that the data collected were not readily available to private consultants. As a result, duplication of effort was required and hence a comprehensive data collection program for the Mound Basin (heretofore never accomplished) had to be initiated.

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### HISTORY AND CURRENT STATUS OF BASIC DATA

Historically, the systematic collection of data and evaluation of the ground water resources of Ventura County have been performed by the California Department of Water Resources and were published in 1933, 1953 and 1959. Numerous additional surface and ground water studies of the area have been previously conducted by various private consultants. A complete list of references used in this study is presented in the Bibliography at the end of the report.

Ventura County Flood Control District continued a portion of the water level and water quality data collection program established by the Department of Water Resources for their 1953 and 1959 Ventura County investigations. Lack of funds curtailed much of the Flood Control District's data collection program in 1967. Only limited and sporadic data have been collected in the past several years. At present, the District periodically monitors less than 10 wells in the Mound Basin.

United Water Conservation District monitors water level and water quality in many wells within their entire service area. For the Mound Basin, this data collection effort includes seven wells.

The City of San Buenaventura occasionally monitors water levels in City-owned wells near the basin. Water qualities are determined frequently since their production is used in the City supply system. The "Montalvo Well" (well number 2N/22W-17Q4) represents the only City-owned well currently operating in Mound

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Basin. The City-owned "Saticoy Well" (2N/22W-2K6) is located in the Santa Paula Basin, east of Mound Basin, while City-owned "Golf Course Wells # 2, 3 and 4" (2N/22W-20QI, 20L2, and 20J1, respectively) are located in the Oxnard Plain Basin south of Mound Basin. All City-owned wells, including "Golf Course Well # 1" (2N/22W-20L1) which has been abandoned, are shown wherever possible on Plates 3 thru 6, Geotechnical and Hydrogeologic Sections. (See Appendix A - Water Well Identification System, for details on the United States Geological Survey well number scheme which will be used in this report.)

A water resources management study was initiated in 1969 as a cooperative agreement between the State Department of Water Resources and Ventura County Flood Control District to produce a ground water model for the Oxnard and Mound Basin areas. As a part of this study offshore subsurface data are being provided by the United States Geological Survey utilizing geophysical methods.

All of the located water wells and the wildcat oil wells for which data are available are shown on Geotechnical Map - Plate 2. No effort was made during the investigation to canvass the entire basin and delineate those wells which are still currently useable and/or active. The water wells denoted on Plate 2 include essentially all those that have been drilled in the area since the 1920's. Many of the boring logs from the older wells may not be accurate and, in some cases, may be fictitious. However, no well logs were discarded on this study.

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All available water well logs were obtained from the Ventura County Flood Control District, the United Water Conservation District, and the State Department of Water Resources. These agencies also provided water level and water quality data. Water wells with available boring logs are specially denoted on Plate 2. Water wells with any available historical water level data are specially denoted on Plates 7 through 9 - Ground Water Contours.

As can be seen on these plates, there is a general lack of boring log and water level data in the vicinity of the area outlined in the initial scope of this report, that is, the area along Victoria Avenue north of the Santa Paula Freeway. Hence, much of the data had to be projected into these unknown areas. Furthermore, anomalies in the water level data in certain wells, due to either local geologic complexities or inadequacies of the initial data collection method, required the removal of these data.

Inspection of water quality records indicated a paucity of good, long-term and basin-wide coverage. Also revealed was a great variability in the concentrations of ions in the analyses for individual wells from one analysis to another and from one well to another of similar depth and aquifer penetration. This could be due to the fact that most wells in the basin are perforated in aquifers of different age and also that the original sampling may have been poor.

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Oil well data, including electric logs and boring logs, to depths of 5000 feet were obtained from the State Division of Oil and Gas. These wells are specially denoted on Plate 2. It should be noted that several wildcat oil wells were drilled in the southern part of the basin in the 1920's and contain boring logs which may possibly be inaccurate.

No attempt has been made in this study to check the accuracy or validity of any of the raw data.

#### ACKNOWLEDGEMENTS

The cooperation of Mr. Richard Farnsworth of the United Water Conservation District and Mr. John Turner of the Ventura County Flood Control District is gratefully acknowledged. Permission to review previous reports and to reproduce basic data on file at their respective agencies aided the initial operations of this investigation.

The assistance of Messrs. Richard Dettloff, Harry Darten, and William Moran of the City of San Buenaventura, Water Department, who supplied valuable previous reports and subsurface data for City-owned wells, is also much appreciated.

The permission granted by the numerous oil companies, to reproduce important data on file with the California Division of Oil and Gas is also gratefully acknowledged.

Personal communication and discussions with Dr. H. Gary Greene of the United States Geological Survey concerning recently acquired offshore geophysical data were also helpful to this study.

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## FINDINGS

### AREA OF INVESTIGATION

General. This investigation focuses principally on the Victoria Avenue region of the Mound Ground Water Basin which represents the westernmost basin within the Santa Clara River Valley drainage (See Plate 1). The basin is approximately seven miles long and four miles wide and contains approximately 17,000 acres. The boundaries of the basin totally encompass the City of San Buenaventura. 764

The term "Mound Basin" will be used synonymously with the term "Mound Ground Water Basin" in the remainder of this report and will be defined by those boundaries shown on Plate 1.

Physiography. Mound Basin consists of a low lying alluvial plain which rises gradually northward toward the bordering foothills.

The lower ground surface elevations in the basin are located along the Pacific coastline at the western boundary of the basin (sea level) and along the southern boundary of the basin north of the Santa Clara River (approximately 50 feet above sea level).

From these two areas, the ground surface gradually rises to approximately 400 feet above sea level at the base of the foothills. The highest elevations in Mound Basin are approximately 900 to 1000 feet above sea level and occur in the foothills along the northern boundary.

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Surface waters of the basin drain southerly to the Santa Clara River and thence westerly to the Pacific Ocean, except for those areas nearer the City of San Buenaventura which drain directly to the ocean. Principal drainage channels include Arundell and Harmon barrancas.

Climate. A Mediterranean-type climate typical of southern California coastal areas prevails in the Ventura area. Summers are generally long, warm, and dry and are followed by shorter, wet winters having cooler temperatures. Proximity to the ocean provided a moderating effect on the climatic conditions; frosts generally are rare.

Approximately 80 percent of the average annual precipitation occurs during the months of December through March. Table 1 based on the 100-year period 1867 to 1967 reveals this relationship.

TABLE 1 - Average Monthly Precipitation

| Month | Average<br>Precipitation<br>(inches) | Month | Average<br>Precipitation<br>(inches) |
|-------|--------------------------------------|-------|--------------------------------------|
| Oct   | 0.51                                 | Apr.  | 1.03                                 |
| Nov.  | 1.33                                 | May   | 0.30                                 |
| Dec.  | 2.80                                 | June  | 0.05                                 |
| Jan.  | 3.45                                 | July  | 0.01                                 |
| Feb.  | 3.21                                 | Aug.  | 0.01                                 |
| Mar.  | 2.42                                 | Sept. | 0.19                                 |

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As determined by the Ventura County Flood Control District, the mean precipitation for the Ventura area is 15.42 inches for their base period which is 1867-68 to 1943-44, inclusive. Precipitation data for the rainfall seasons 1867-68 to the present are given in Appendix AA- Precipitation Data, along with the index of wetness for each year which relates a single year's precipitation to the mean precipitation for the chosen base period.

Runoff in the Santa Clara River, located south of Mound Basin, is directly proportional to storm activity in the region and hence varies greatly from season to season and year to year.

Present Land Use. The Santa Clara River Valley, the coastal plain, and portions of the Ventura River area have been extensively developed with agriculture. Urbanization, particularly in areas south and east of the city limits of the City of San Buenaventura, has been increasing in recent years.

Recent land use surveys indicate that there are approximately 4980 acres of irrigated agricultural land and 7155 acres of urbanized area within Mound Basin. The remaining 4865 acres of land within the basin consist of natural, undeveloped foothill areas forming the northern portion of the basin.

Principal crops on the numerous farms and ranches in the area include citrus, walnuts, and truck crops. The oil industry has also been active in and around Mound Basin. Large producing oil fields are located north, south, and southeast of the basin as represented by the Ventura, West Montalvo, and

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El Rio oilfields, respectively. Numerous wildcat oil wells have been drilled within Mound Basin but no producing fields have been developed within its boundaries (See Plate 2).

Water service to Mound Basin is presently provided by public systems and by numerous private individuals who pump from their own wells. The Ventura River Municipal Water District and the City of San Buenaventura supply the west end of the basin. The United Water Conservation District is the major supplier servicing the eastern three-fourths of the basin.

Most early ground water development within Mound Basin utilized shallow wells penetrating only Recent and Upper Pleistocene alluvial deposits. More reliable supplies were subsequently produced as wells were drilled deeper and penetrated aquifers within the underlying San Pedro formation. Many of the deeper wells which currently exist in Mound Basin are perforated in both the alluvial deposits and the San Pedro formation.

#### HYDROGEOLOGY

General. The Santa Clara River Valley overlies one of the major marine sedimentary basins in the Transverse Range geomorphic province. At least 30,000 feet of marine and continental sediments have been deposited in the basin during Tertiary and Quaternary time.

In Mound Basin alluvial deposits and the San Pedro formation represent the principal water bearing strata.

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Underlying deposits, which include the Santa Barbara and Pico formations, are considered non-water bearing in the Mound Basin area although they yield limited amount of water for domestic wells elsewhere in Ventura County (See Plate 3 - Geotechnical Sections).

#### Water-Bearing Formations

Alluvial Deposits. Undifferentiated Recent and Older alluvium comprise the water-bearing alluvial deposits in the Mound Basin. These deposits consist of unconsolidated materials much of which was eroded from the northern slope of the basin and deposited by streams in alluvial fans and flood plain areas across the basin. It is generally difficult to separate Recent from Older alluvium since they occur in lenticular strata and often interfinger.

Undifferentiated Recent alluvium is composed of flood plain and active river deposits in the vicinity of the Santa Clara River, and of fan deposits which mantle much of the remaining portion of the basin. (See Plate 2.) These materials consist of interstratified and lenticular clays, silts, sands, and gravels. Recent alluvium attains a maximum thickness of approximately 290 feet near the southwestern corner of Mound Basin. These deposits unconformably overlie Older alluvium.

In the Oxnard Plain Basin, adjacent to and south of the Mound Basin, Recent alluvium is reportedly nearly 250 feet thick and contains a permeable, coarse grained unit at its base known as the Oxnard Aquifer. As seen on Plates 4 through 6 - Hydrogeologic Sections, this aquifer has been traced into the Mound Basin.

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Undifferentiated Older alluvium is of Upper Pleistocene age and unconformably overlies the San Pedro formation. Remanant exposures of Older alluvium which blanket the southern and western flanks of the foothills along the north side of Mound Basin are known as terrace deposits (see Plate 2).

As seen on Hydrogeologic Sections, Plates 4 through 6, Older alluvium can be divided into an upper and lower portion. The upper portion consists principally of confining zones, represented by clay and silty clay with minor amounts of sand and gravel. These generally impermeable materials have caused the confinement of underlying water-bearing strata. Interstratified sand and gravel with variable amounts of clay comprise the lower portion of these deposits.

The basal, coarser grained portion is thickest near the Santa Clara River but becomes generally thinner toward the foothills. A similar coarse-grained basal zone, known as the Mugu Aquifer, has previously been identified in the Oxnard Plain Basin and is traced with difficulty northward the Santa Clara River. As used in this report, the coarse-grained strata at the base of the Older alluvium in Mound Basin are considered equivalent to the Mugu Aquifer and will be known as such. Most wells in Mound Basin contain perforations in the Mugu Aquifer.

Older alluvium varies in thickness from about 125 feet in the eastern part of the basin to about 320 feet nearer the coast. (See Plates 4 thru 6.) The elevation of the base of Older alluvium near the coast (-530 feet below sea level) is in good agreement with offshore data recently acquired by the United

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States Geological Survey (Dr. H. Gary Greene, personal communication).

Marine fossils obtained from outcrops of Older alluvium near the City of San Buenaventura indicate a near-shore, shallow water origin. Lack of fossils in outcrops farther inland suggests a continental origin.

San Pedro Formation. Deposits of the San Pedro formation are of Lower Pleistocene age and underlie the alluvial deposits in Mound Basin along a marked angular unconformity. Exposures of the San Pedro formation encompass an area of approximately 3000 acres in the foothills forming the northern portion of the Mound Basin. They attain a maximum thickness of approximately 2300 feet in this region (Plate 3). The thickness of the San Pedro formation is only about 500 feet at the southern edge of the Mound Basin as a result of complex folding and faulting and subsequent erosion in this area (See Plates 3,4,5).

Upper portions of the San Pedro formation contain variable amounts of clay and silty clay with smaller amounts of sand. A series of water-bearing sands in this section have been named the Hueneme Aquifer in the Oxnard Plain Basin. Structural complexities and erosion have removed these beds in the southern part of the Mound Basin. Farther north in the basin this aquifer cannot be identified with assuredness.

Lower portions of the formation consist principally of sand and gravel zones with variable thicknesses of interstratified clay and silt. Well log data, as depicted in part on Plates 4 to 6 indicate that the coarser grained, potentially water-

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bearing strata are somewhat lenticular and become generally thinner in a northerly direction across the basin.

Fossils are locally abundant in the middle and lower portions of the formation and indicate a shallow marine environment. The fossil evidence and the finer grained sediments common in the upper portion of the formation suggest a continental origin with deposition by slow-moving streams. In this environment, coarse-grained deposits would result from random flooding conditions and would occur mainly as lenses. Furthermore, sea level fluctuations caused by glacial and interglacial period were common during the time of deposition of the entire formation and would help create the widespread lenticularity which is common throughout these deposits.

From its outcrops in the foothills on the north side of the basin, the San Pedro formation extends westerly under the alluvium of the Ventura River with a final zone of outcrops on the west of the Ventura River before it disappears offshore. Ocean bottom contours indicate minor irregularities paralleling the strike of the formation suggesting it may have offshore exposures.

Recent geophysical data indicate that the San Pedro formation extends several miles offshore west of Mound Basin; the fresh water-salt water interface is approximately  $5\frac{1}{2}$  miles offshore (Dr. H. Gary Greene, personal communication). This region would contain a substantial ground water storage.

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The predominantly sand and gravel zone located at or near the base of the San Pedro formation is known as the Fox Canyon Aquifer in the Oxnard Plain Basin. This basal aquifer has never been encountered in water wells in the Mound Basin as defined herein. (City-Golf Course Well #4, 2N/22W-20 Q1, located just south of the Mound Basin did encounter and presently produces from this zone as seen on Plate 4. However, we believe sufficient evidence is at hand to suggest that the Fox Canyon Aquifer is present in Mound Basin. Unfortunately its exact thickness, extent, transmissibility and storage capacity cannot be accurately defined.

Exposures near the base of the San Pedro formation in the foothills on the north side of Mound Basin do not indicate the same aquifer thickness nor sediment coarseness as at the type locality of the Fox Canyon zone on the south flank of South Mountain, several miles south east of the basin. This aquifer is quite continuous and traceable across the Oxnard Plain Basin south of the Santa Clara River. However, these beds apparently partially pinch out and become more lenticular in a northerly direction across Mound Basin.

In the Mound Basin, as in surrounding areas, the Fox Canyon Aquifer can be used as an aid in defining the base of the San Pedro formation and hence, the apparent base of fresh water,

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The Fox Canyon zone is immediately underlain by sandy silts approximately 50 to 150 feet thick which is, in turn, underlain by a sandy gravel zone approximately 50 to 140 feet thick. (See Plates 4 and 5.) The gravel forms the basal unit of the San Pedro formation and often portrays a strong signature of high resistivity on electric logs. This is in sharp contrast to the shales of the underlying Santa Barbara formation which have a minimum electrical resistivity caused by saline connate waters still present in these fine-grained sediments.

As revealed on a few electric logs of oil wells north of the Santa Clara River, the Fox Canyon Aquifer varies from approximately 200 to 300 feet in thickness (See Plate 4 thru 6). Due to the complete lack of deep wells in the vicinity of the proposed well development along Victoria Avenue the exact depth and thickness of this aquifer in the area is not known. Barring any as yet unknown structural deformation in this area and projecting data from existing oil well logs, depth to the Fox Canyon Aquifer in the vicinity of Victoria Avenue as shown on Plates 4 and 6 is approximately 2200 feet.

In contrast to the generally recognizable signature of the Fox Canyon Aquifer and basal gravels on electric logs, the middle and upper portions of the San Pedro formation are not nearly as well defined and are difficult to correlate due to lenticularity.

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### Non-Water-Bearing Formations

Santa Barbara Formation. Sediments of the marine Santa Barbara formation conformably underlie the principal water-bearing deposits of the San Pedro formation in Mound Basin. The Santa Barbara formation ranges in age from Upper Pliocene to Lower Pleistocene and consists of blue to brown mudstone, sandy and silty shale and minor sandstone. Fossil evidence indicates a marine origin with deposition occurring in shallow to moderate depths of water.

As shown on Geotechnical Sections - Plate 3, the thickness of the Santa Barbara formation varies from about 2500 feet on the north side of the Mound Basin to about 1900 feet along the southern boundary of the basin. Farther south, the Santa Barbara formation decreases to a thickness of about 800 feet near the southern portion of the Oxnard Plain Basin.

No wells in Mound Basin produce water from the Santa Barbara formation and it contains no useable aquifers in this area. Farther to the south near the south flank of Oak Ridge and in portions of the Oxnard Plain, the upper section of the Santa Barbara formation contains a permeable zone of sand and gravel known as the Grimes Canyon Aquifer. This aquifer cannot be traced to the Mound Basin.

Inspection of electric logs from wildcat oil wells in the vicinity of Mound Basin indicate that these strata contain only brackish water. Locally, within the upper 100 to 200 feet of this formation, minor amounts of water of somewhat fresher character are revealed on the electric logs. This water has seeped downward from the overlying San Pedro formation and is

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probably not recoverable.

Pico Formation. Strata of the Pico formation of Pliocene age conformably underlie the Santa Barbara formation and are reportedly as much as 12,000 feet thick. The Pico formation is of marine origin and consists of sandstone with interbedded shale. These rocks are considered non-water-bearing in the Mound Basin area.

They are difficult to separate from the overlying Santa Barbara formation by the use of electric log data only. To accurately distinguish these two formations requires paleontological information that was not available to this study.

#### STRUCTURE

General. Folding and faulting are the major structural features in the vicinity of the Mound Basin. These features exhibit general east-west trends which conform to the east-west structural fabric so prominent in the Transverse Range geomorphic province.

Most of the folding and faulting occurred during the major Middle Pleistocene orogeny. That the activity has continued at least into late Upper Pleistocene time is evidenced by the angular unconformity between these deposits and the underlying San Pedro formation, by the unconformity between Older and Recent alluvium, and by the faulting which has created ground water barriers adjacent to Mound Basin. As no surface traces of the faults have been observed, it is unknown whether the activity has continued into the Recent.

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Bedding attitudes in the exposures of the San Pedro formation in the foothills strike generally east-west and dip south at angles varying from approximately 20 to 60 degrees from the horizontal. Attitudes in the overlying terrace deposits at the base of the foothills have a similar strike but dip south at angles generally less than 12 degrees from the horizontal. Attitudes of the beds in rocks older than the San Pedro formation are generally conformable to those in these deposits as revealed on Geotechnical Map - Plate 2.

Folds. The east-west trending Santa Clara River syncline, a pronounced fold in the Mound Basin, is known to extend along the course of the entire Santa Clara River Valley. Recent data reveal that it continues offshore west of Mound Basin for several miles (Dr. H. Gary Greene, personal communication). The surface trace of its axial plane, as indicated on Plate 2, is subparallel to the Santa Paula Freeway. Meager data suggest that both limbs are relatively flat, with maximum dips being probably less than 10 to 15 degrees (See Geotechnical Sections, Plate 3.)

The origin of the syncline is probably related to compressional forces and subsequent movement along major faults which border the valley on its northern and southern sides, principally the Oak Ridge and Pitas Point fault system. The syncline was initially folded, and faulting occurred later as the limbs of the fold became steeper. The syncline may plunge slightly westward.

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Uplifting and erosion along the northern limb of the syncline in the Mound Basin have created the exposures of the San Pedro formation, thus allowing them to transmit surface precipitation via deep percolation into ground water storage in the basin.

The southern limb of the syncline has been partially eroded and is now buried beneath Recent and Older alluvium in the vicinity of the Montalvo anticline which forms the southern boundary of Mound Basin. The north-dipping and truncated edges of the strata of the San Pedro formation in this area are in hydraulic continuity with overlying alluvial deposits.

The Montalvo anticline is another hydraulically important fold in Mound Basin. The surface trace of the axial plane of this complexly faulted fold is located near the Santa Clara River as shown on Geotechnical Map - Plate 2. This surface has been chosen as the southern boundary of the Mound Basin. To be sure there is continuous lateral communication in the alluvial deposits across this boundary, sufficient vertical communication must also exist between the alluvial deposits and underlying San Pedro formation to convey recharge into the older strata. However, it is only along the north-dipping limb of the anticline that ground water can be transmitted into storage within the San Pedro formation in the Mound Basin. Percolating ground water on the south-dipping limb of the fold is conveyed into storage in this formation within the Oxnard Forebay or Oxnard Plain basins.

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Other folds, notably the Ventura anticline and the Oxnard-Las Posas syncline, also occur in the greater Ventura region but neither is present in Mound Basin. The approximate surface traces of their axial planes are shown on Geotechnical Map - Plate 2.

Faults. Based on oil field data, the Pitas Point fault is located near the base of the foothills along the northern edge of Mound Basin (See Plate 2). Its alignment transects the City of San Buenaventura from whence it continues in a more northwesterly direction eventually disappearing offshore near the mouth of the Ventura River. In this offshore region, it is likely that it connects with a fault which is revealed on geophysical data to exhibit rather recent movement (Dr. H. Gary Greene, personal communication).

Available data on the Pitas Point fault indicate a 60 to 70 degree dip to the north; the northern side of the fault has been upthrown relative to the southern side. Displacement within the San Pedro formation is approximately 400 to 600 feet (see Geotechnical Sections, Plate 3).

There have been no surface ruptures observed to date near the base of the foothills that can be attributed to activity on the Pitas Point fault. Due to a lack of water level data in this area, it is unknown whether this fault severs hydraulic continuity between the foothill areas and the remainder of the basin south of the fault.

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The east-west trending Oak Ridge fault system (See Plate 2) is a major fault in the western portion of the Santa Clara River Valley. Its alignment is along the southern boundary of the valley from Saticoy to an area two miles southeast of Piru where it is terminated by the Santa Susana fault. Westward from Saticoy, its alignment is more complicated and less well delineated. Recent data suggest that it can be traced for some distance offshore from the mouth of the Santa Clara River. The existence of the topographic highs (mounds) in the southern portion of Mound Basin is probably related to movement along this system.

The fault zone has been investigated by numerous oil companies since it has created several oil reservoir traps. Available data from the Saticoy oil field southeast of the Mound Basin indicate the fault has caused as much as 15,000 feet of vertical displacement in the subsurface.

Displacement of the Oak Ridge fault in Mound Basin has probably been as much as 1700 feet. This displacement has been extended upward into the San Pedro formation to within approximately 500 feet of the ground surface. It cannot be shown to have displaced alluvial deposits (see Hydrogeologic Sections, Plates 4 and 5).

Oil field data indicate the dip of the Oak Ridge fault is variable, ranging from 55 to 85 degrees to the south. The southern side of the fault has been upthrown relative to the northern side.

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The McGrath fault is another east-west trending fault and is located near the southern boundary of the Mound Basin. It may represent a more recent branch of the Oak Ridge fault system and apparently joins this system in the vicinity of the southeastern corner of the Mound Basin (See Plate 2).

Oil field data reveal 60 to 80 degree southerly dips on the McGrath fault, with the southern side of the fault thrust upward relative to the northern side. Displacement within the San Pedro formation in the Mound Basin has been approximately 100 to 400 feet. Fault displacement along the McGrath fault has been extended to within 400 feet of the ground surface and hence at least to the base of Older alluvium (See Plates 5 and 6).

The Country Club fault trends northwesterly along the eastern edge of the Mound Basin and forms much of the boundary between this basin and the Santa Paula Basin to the east. Oil well data indicate a displacement of 1600 to 1800 feet (See Plates 3 and 6) with the southerly side of the fault displaced upward relative to the northerly side. Dip is unknown and is assumed to be vertical. This fault acts as a barrier to ground water movement with water levels on the north side of the fault remaining historically higher than those in the Mound Basin on the south side of the fault.

At least two other unnamed faults exist in the Mound Basin (See Plate 2). One is located in the south central part of the basin; oil field data indicate that the east side has been uplifted relative to the west side. This fault probably helped create the topographic highs (mounds) in this area.

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The other fault is near the southeastern corner of Mound Basin. Oil field data indicate that the east side of this fault has been uplifted relative to the west side. Both faults may be related to activity along the Oak Ridge fault system.

#### GROUND WATER MOVEMENT AND WATER LEVELS

Ground water contours in Mound Basin indicate that movement is from the northeast to the south and southwest. The historical direction of movement is generally consistent with the variation in surface topography across the basin. Since most of the historical data for these contours are based on relatively shallow wells, it can be assumed that they principally reflect movement within the Upper Pleistocene Older alluvium.

Water movements in the San Pedro formation are difficult to describe due to a paucity of data from wells perforated solely in these strata. It can be assumed that water would percolate down the limbs and toward the axis of the Santa Clara River syncline and thence westward along the plunge of the fold toward its submarine outcrops.

Ground water levels in Mound Basin have been contoured for fall 1944, fall 1957, and spring 1972 in order to depict a general basin high, a basin low, and present basin levels, respectively. See Plate 7 thru 9, Ground Water Contours.

Fall 1944 (see Plate 7) represents a time of high ground water levels created by a prior period of wet years and minimal ground water extraction. Most noticeable on Plate 7, is the zone of flowing wells along the beach area which extended nearly 3 miles eastward along the Santa Clara River from its mouth.

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Also noticeable is the westerly slope of water levels and contour re-entrants along the southern boundary of the basin; these indicate recharge to Mound Basin from the Santa Clara River and the Oxnard Forebay Basin. A smaller portion of this recharge may come from the Oxnard Plain Basin. Recharge would be transmitted through the alluvial deposits.

During this basin high period, the ground water level in the vicinity of Victoria Avenue <sup>and the Santa Paula Freeway</sup> was at an elevation of about +45 feet, which represents a 205-foot depth below ground surface.

Fall 1957 (See Plate 8) represents a period of low ground water levels caused by a long drought and increased ground water extractions. The years of 1951 and 1962 also has similarly low levels but were not contoured. As seen on Plate 8, there was a large area within the basin which contained water elevations below sea level. Subsea water elevations were also particularly prominent along the Santa Clara River.

In Fall 1957, in the vicinity of Pierpont Bay, an apparent reversed gradient existed from the coastline to a region between wells 2N/23W-14M1, and 14L1-L2. Whether this was actually sea water intrusion or only a reflection of overdraft in the Oxnard Aquifer caused by coastal plain wells is difficult to say. There was only a slight increase in chloride ion concentration in the Pierpont Bay wells in this period.

It is interesting to note that the contour re-entrants on the south side of the basin are poorly defined in Fall 1957 compared to those revealed in Fall 1944. This indicates lessened recharge from the Oxnard Forebay Basin and subnormal flows in

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the Santa Clara River caused by general drought conditions.

During this basin low period, the ground water level was in the vicinity of Victoria Avenue at an elevation of about +15 feet which represents a 235 foot depth below ground surface.

Spring 1972 levels (see Plate 9) reveal current trends in the basin. Water levels are presently returning toward their previous highs although there is no large zone of flowing wells as appeared in Fall 1944. Contour re-entrants in the southern part of the basin again indicate recharge from the river and ground water basins south of Mound Basin.

Present water levels along Victoria Avenue are essentially the same as those in 1944 -- about 205 feet below ground surface.

All three countour maps also reveal the existence of a ground water barrier at the eastern boundary of Mound Basin created by the Country Club fault. The fault probably restricts ground water movements within the San Pedro formation between Mound Basin and Santa Paula Basin to the east. The fault may also restrict lateral hydraulic communication even within most of the alluvial deposits across the fault. Water levels have historically remained consistently higher northeast of the fault in the Santa Paula Basin.

The contour maps also suggest that fault activity in the southern part of the Mound Basin has not severed hydraulic communication within the alluvial deposits between the 3 ground water basins in this area. Locally, there are a few anomalous

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water levels and possibly some fault-induced water level changes. However, the entire fault effect is masked and certainly no continuous zone of severed hydraulic communication exists in this area.

All 3 contour plates also suggest there is little indication of major recharge from the foothills on the north side of the basin. However this may be due to a general lack of water level data in this area.

#### HYDROGRAPHS

Hydrographs of periodically monitored wells in Mound Basin have been obtained and are presented on Plate 10 - Well Hydrographs. Water level fluctuations near the coast are represented on Plate 12 by the hydrograph for wells 2/23-1401, 14L1, 14K1, located relatively close to one another in the western portion of the basin. The hydrograph for well 2/23-24G1 located near the southwestern boundary of the basin, and that for wells 2/22-9K3 and 9K4 located in the northeasterly part of the basin are also shown on Plate 12. The latter two wells are located approximately 1-1/3 miles east of the intersection of Victoria Avenue and the Santa Paula Freeway and provide the only long-term record of water level fluctuations in the vicinity of the proposed development.

The hydrograph of the wells in Section 14 reveal that high ground water levels and a flowing well condition existed in the area until 1946. Lower ground water levels were prominent between 1946 and 1962 although this period was characterized by many up and down fluctuations. The years of 1951, 1957, and 1961 denote the lowest water levels. Levels during the last

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10 years suggest an upward trend. The entire hydrograph shows a typical pressure effect caused by confinement within this area; individual water level fluctuations are marked and rapid.

The hydrograph for the well in Section 24 did not begin until 1948 and does not reveal any early period of flowing conditions. Between 1948 and 1961 is a period of low water levels with the years of 1951, 1957 and 1959 being the lowest of the group. The hydrograph indicates the many up and down fluctuations during this period which were also revealed on the hydrograph of wells in Section 14. However these fluctuations are somewhat more subdued than those in the Section 14 wells, probably indicating less confinement of the aquifers in the vicinity of Section 24. The last 10 years of the Section 24 hydrographs reveals a rising trend of water levels.

The hydrograph for wells in Section 9 shows flowing water levels in the early 1940's, followed by a 15-year period of low water levels with many individual up and down fluctuations. The years of 1951, 1957, 1959, and 1961 were the lowest in this period. The last 10 years of the hydrograph are characterized by a rising trend in water levels. Aquifers in this area may not be strongly confined since there is a general absence of the marked and rapid water level fluctuations as seen in Sections 14 and 24.

Many of the long and short-term fluctuations revealed on all 3 hydrographs correlate generally well with precipitation records for the same period and, hence, with runoff hydrographs for the Santa Clara River. Also, all 3 hydrographs reveal that there has been no general long-term decline in water levels in their

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respective areas within the Mound Basin which might indicate basin overdraft. It is also apparent that even though the basin is grossly confined by impermeable strata, there is sufficient hydraulic continuity to allow vertical communication of water through the alluvium into the underlying San Pedro formation.

Well logs from wells 2/23-14L1, 14K1, and 24G1, indicate they are deep enough to penetrate several aquifers within the San Pedro formation. The depths of wells 2/22-9K3, and 9K4 are sufficient to penetrate only a few of the aquifers in the upper portion of the San Pedro formation. Undoubtedly, all the wells are perforated and receive water from both Older lluvium and San Pedro formation. Historical records of pumpage on file with the State Division of Water Rights reveal that the deeper wells (14L1, 14K1, 24G1) produce larger quantities of water than the shallower wells (9K3, 9K4).

#### GROUND WATER EXTRACTIONS

The State Division of Water Rights requires individuals having wells which pump in excess of 25 acre-feet per year of water to file an annual record of total extractions. Summation of available records for wells in Mound Basin for the period 1967 through 1971 yielded the data in Table 2.

TABLE 2  
GROUND WATER EXTRACTIONS 1967 - 1971

| Year | Mound Basin<br>Pumpage<br>(Acre-Feet) | Pumpage from 2 City<br>Golf Course Wells<br>(Acre-Feet) | Total Extraction<br>If City Wells In-<br>cluded (Acre-Feet) |
|------|---------------------------------------|---------------------------------------------------------|-------------------------------------------------------------|
| 1967 | 7100                                  | 1782                                                    | 8882                                                        |
| 1968 | 7289                                  | 1594                                                    | 8883                                                        |
| 1969 | 6527                                  | 3811                                                    | 10338                                                       |
| 1970 | 7018                                  | 3846                                                    | 10864                                                       |
| 1971 | 6688                                  | 3874                                                    | 10562                                                       |

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It can be seen that the total reported extraction in Mound Basin has averaged approximately 6900 acre-feet per year during the past 5 years. It is interesting to note even though the extractions from City-owned wells near the Municipal Golf Course (Golf Course Well #4, 2/22-20J1, and Golf Course Well #3, 2/22-20L2) have increased greatly in the last 3 years, that water levels in Mound Basin indicate an overall rising trend during this same period (See Plate 10). This fact suggests that the bulk of the extractions of these wells is from the San Pedro formation and that these strata in this area are not in direct hydraulic continuity with similar strata in the Mound Basin. This is also depicted on Plates 3 and 4 - Geotechnical and Hydrogeological section A-A', AA-AA', which shows these Golf Course wells are located on the south limb of the Montalvo anticline and hence outside the Mound Basin boundary.

The final column in Table 2 was included only to serve as a comparison with extraction figures prepared by other investigators. The Department of Water Resources (1953) estimated a safe yield of 8800 acre-feet per year for a basin similar to the Mound Basin defined herein but one which included the area of the Municipal Golf Course. It should be noted that only one of the City's Golf Course wells was in existence in 1953, at which time the majority of City extractions was coming from the Pierpont Bay area. Stetson, Strauss, and Dresselhaus (1959) indicated a pumpage of 13,500 acre-feet per year for the period 1953 to 1958 for a basin roughly similar to that as defined by the State. Boyle Engineering (1965) estimated an extraction of

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11,000 acre-feet per year for a similar basin. Due to differences in basin boundaries between these various investigators it is difficult to relate these figures.

For the Mound Basin as defined herein, a safe yield of 9000 to 10,000 acre-feet per year can be utilized since water levels in the basin have been increasing in recent years even though basin extraction has remained relatively constant or increased slightly since 1967. Furthermore, there are an estimated 4980 acres of agricultural land to be irrigated in Mound Basin (based on a modified Ventura County Land Use Survey). Assuming an average water use of 2 acre-feet per year per acre of land for irrigation, it will require about 9,960 acre-feet per year of applied water. The excess of this figure over that on file with the State (average 6,900 acre-feet per year) is supplied principally by precipitation on the basin extractions not reported to the State.

#### WATER QUALITY

General. Concentrations of mineral constituents in ground water are influenced primarily by the quality and quantity of water which percolates to the ground basin. The sources of this replenishment by percolation include surface flow, precipitation, subsurface inflow from adjacent areas, sewage and industrial waste waters, and irrigated waters. Ground water quality is also influenced by lithologic type and relative age of water-bearing materials; the hydrogeologic conditions that govern the rates of ground water movement; well construction and abandonment techniques; changes in water level elevations; and duration and rate of pumping prior to sampling of the ground water.

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Mound Basin. Principal sources of ground water in Mound Basin include precipitation on the basin, influent seepage from the Santa Clara River, and seepage from the Oxnard Forebay and Oxnard Plain basins. Present ground water extractions come from aquifers in the alluvial deposits and those in the upper and middle portions of the San Pedro formation. Due to structural complexities and lenticularity in the San Pedro formation it is possible that all strata within the formation have not been completely flushed of their original connate water. Inspection of electric logs indicates that certain strata within the formation may contain water which is still mineralized and hence of inferior quality. These incompletely flushed strata appear to be in random occurrence and are not grouped in any zone or location.

To study water quality, wells in the basin were divided into 3 categories on the basis of depth. The 3 depth categories chosen include wells less than 300 feet deep, wells from 300 to 700 feet deep, and wells greater than 700 feet deep. Available analyses for individual wells in each depth category were then subdivided on the basis of date of sampling and analysis. Selected time period include 1940-1949, 1950-1959, and 1970 to present.

The following tables depict results of this method of analyses.

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## TABLE 3

ANALYSES OF GROUND WATER IN SELECTED WELLS, 1940-1949



| WELL No. | NUMBER<br>OF ANALYSES | ION CONCENTRATIONS in parts per million |    |      |                  |                 |    |                 |   |     |
|----------|-----------------------|-----------------------------------------|----|------|------------------|-----------------|----|-----------------|---|-----|
|          |                       | Ca                                      | Mg | Na+K | HCO <sub>3</sub> | SO <sub>4</sub> | Cl | NO <sub>3</sub> | B | TDS |

DEPTH 0-300 feet

NO ANALYSES AVAILABLE

DEPTH 300-700 feet

|            |   |     |    |     |     |     |    |   |     |      |
|------------|---|-----|----|-----|-----|-----|----|---|-----|------|
| 2N/22W-9K2 | 2 | 152 | 44 | 140 | 357 | 462 | 70 | 0 | .82 | 1225 |
| 9K3        | 2 | 137 | 39 | 130 | 344 | 393 | 56 | 0 | .48 | 1099 |
| 9K4        | 1 | 139 | 45 | 112 | 350 | 391 | 66 | - | .4  | 1103 |
| 9L2        | 1 | 164 | 51 | 157 | 395 | 508 | 88 | 0 | .66 | 1364 |
| 16 C1      | 1 | 170 | 60 | 175 | 300 | 695 | 65 | - | .7  | 1315 |
| 17 Q1      | 1 | 130 | 41 | 118 | 235 | 464 | 50 | - | -   | 1038 |
| 20 M1      | 2 | 135 | 41 | 133 | 259 | 454 | 51 | 0 | .6  | 1072 |

Average = 147 47 138 330 481 64 0 .6 1181

DEPTH > 700 feet

|            |   |     |    |     |     |     |     |   |     |      |
|------------|---|-----|----|-----|-----|-----|-----|---|-----|------|
| 2N/23W-2K1 | 1 | 164 | 60 | 210 | 421 | 579 | 103 | - | .46 | 1526 |
| 10R1       | 3 | 161 | 46 | 144 | 317 | 494 | 72  | 6 | .5  | 1234 |
| 13F1       | 1 | 155 | 47 | 152 | 393 | 471 | 75  | - | .67 | 1192 |
| 14K1       | 5 | 158 | 43 | 176 | 396 | 530 | 74  | 0 | .6  | 1377 |
| 14L1       | 2 | 168 | 46 | 163 | 411 | 490 | 75  | - | .62 | 1353 |
| 14M1       | 2 | 159 | 45 | 169 | 385 | 476 | 76  | - | .52 | 1310 |
| 23D1       | 5 | 154 | 42 | 150 | 365 | 443 | 70  | 0 | .48 | 1224 |
| 24G1       | 3 | 144 | 41 | 126 | 335 | 425 | 57  | - | .5  | 1128 |
| 24K1       | 5 | 152 | 44 | 125 | 325 | 463 | 64  | 6 | .5  | 1179 |
| 24K2       | 3 | 166 | 46 | 146 | 361 | 497 | 67  | 4 | .5  | 1287 |

Average = 158 46 156 371 487 73 2 .54 1281

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# ANALYSES OF GROUND WATER IN SELECTED WELLS, 1950-1959

| WELL No. | NUMBER<br>OF ANALYSES | ION CONCENTRATIONS in parts per million |    |      |                  |                 |    |                 |   |     |
|----------|-----------------------|-----------------------------------------|----|------|------------------|-----------------|----|-----------------|---|-----|
|          |                       | Ca                                      | Mg | Na+K | HCO <sub>3</sub> | SO <sub>4</sub> | Cl | NO <sub>3</sub> | B | TDS |

|            |   | DEPTH      |           | 0-300 feet |            |             |            |            |           |             |
|------------|---|------------|-----------|------------|------------|-------------|------------|------------|-----------|-------------|
| 2N/22W-9M1 | 2 | 340        | 124       | 295        | 364        | 1365        | 147        | 94         | .59       | 2730        |
| 10N1       | 1 | 129        | 31        | 97         | 333        | 312         | 41         | 0          | .3        | 812         |
| 17L1       | 1 | 354        | 100       | 284        | 306        | 1320        | 175        | 56         | .6        | 2599        |
| 20B1       | 1 | <u>346</u> | <u>92</u> | <u>241</u> | <u>298</u> | <u>1095</u> | <u>191</u> | <u>163</u> | <u>.6</u> | <u>2474</u> |
| Average =  |   | 292        | 88        | 229        | 325        | 1022        | 136        | 70         | .52       | 2154        |

|            |   | DEPTH      |           | 300-700 feet |            |            |           |            |            |             |
|------------|---|------------|-----------|--------------|------------|------------|-----------|------------|------------|-------------|
| 2N/22W-7R2 | 1 | 168        | 50        | 132          | 353        | 480        | 72        | 17         | .5         | 1154        |
| 8N1        | 1 | 160        | 59        | 168          | 348        | 564        | 77        | 25         | .43        | 1401        |
| 9K2        | 1 | 153        | 57        | 140          | 336        | 528        | 67        | 0          | .56        | 1281        |
| 9K3        | 4 | 144        | 48        | 123          | 346        | 432        | 64        | 0          | .49        | 1157        |
| 9L2        | 1 | 141        | 41        | 155          | 359        | 444        | 67        | 0          | .64        | 1144        |
| 10R2       | 1 | 92         | 30        | 115          | 229        | 345        | 32        | 4          | .6         | 788         |
| 16K1       | 6 | 120        | 40        | 138          | 277        | 456        | 50        | 5.7        | .5         | 1087        |
| 16Q1       | 2 | 179        | 60        | 120          | 287        | 581        | 68        | 18         | .76        | 1313        |
| 17N2       | 2 | 142        | 40        | 133          | 281        | 464        | 76        | 3          | .2         | 1139        |
| 17Q1       | 6 | 135        | 43        | 136          | 267        | 490        | 56        | -          | .73        | 1127        |
| 19J1       | 1 | 139        | 39        | 127          | 260        | 465        | 55        | 1          | .4         | 1079        |
| 20Q1       | 6 | <u>130</u> | <u>42</u> | <u>104</u>   | <u>250</u> | <u>425</u> | <u>47</u> | <u>2.5</u> | <u>.73</u> | <u>1001</u> |
| Average =  |   | 142        | 46        | 133          | 300        | 472        | 61        | 7          | .54        | 1139        |

|                                           |   | DEPTH      |           | > 700 feet |            |            |           |             |           |             |
|-------------------------------------------|---|------------|-----------|------------|------------|------------|-----------|-------------|-----------|-------------|
| 2N/22W-10R1                               | 1 | 133        | 36        | 136        | 268        | 462        | 57        | 0           | .6        | 1057        |
| 17G1                                      | 2 | 150        | 38        | 147        | 246        | 510        | 81        | .5          | .35       | 1173        |
| 18N1                                      | 1 | 153        | 46        | 155        | 327        | 496        | 86        | 2.0         | .66       | 1190        |
| 2N/23W-5L1*                               | 7 | 168        | 55        | 167        | 356        | 464        | 170       | 4.9         | .47       | 1385        |
| 5P1*                                      | 5 | 278        | 75        | 210        | 365        | 483        | 474       | 5.7         | .55       | 1891        |
| 10R1                                      | 3 | 151        | 47        | 142        | 312        | 493        | 75        | 1.0         | .4        | 1221        |
| 13F1                                      | 2 | 152        | 46        | 158        | 385        | 461        | 71        | 1.8         | .65       | 1275        |
| 14K1                                      | 6 | 152        | 36        | 160        | 394        | 430        | 68        | 2.0         | .66       | 1242        |
| 14L1                                      | 5 | 152        | 46        | 164        | 404        | 476        | 74        | -           | .6        | 1316        |
| 14M1                                      | 4 | 151        | 50        | 154        | 382        | 458        | 75        | 2.0         | .45       | 1272        |
| 14N1                                      | 2 | 140        | 42        | 143        | 296        | 474        | 78        | 2.2         | .40       | 1175        |
| 24G1                                      | 8 | 159        | 47        | 130        | 334        | 430        | 72        | 3.0         | .48       | 1175        |
| 24K1                                      | 1 | 142        | 40        | 118        | 272        | 452        | 51        | -           | .50       | 1075        |
| 24K2                                      | 5 | 312        | 87        | 210        | 293        | 990        | 174       | -           | .54       | 2152        |
| 24K3                                      | 5 | <u>156</u> | <u>49</u> | <u>135</u> | <u>334</u> | <u>483</u> | <u>68</u> | <u>12.0</u> | <u>.5</u> | <u>1237</u> |
| Average =                                 |   | 170        | 49        | 155        | 332        | 504        | 112       | 6.2         | .52       | 1332        |
| * Average with these<br>2 wells deleted = |   | 161        | 46        | 150        | 327        | 509        | 79        | 6.4         | .52       | 1284        |

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## TABLE 3

## ANALYSES OF GROUND WATER IN SELECTED WELLS, 1960-1969

| WELL No.                               | NUMBER<br>OF ANALYSES | ION CONCENTRATIONS in parts per million |     |              |                  |                 |      |                 |     |      |
|----------------------------------------|-----------------------|-----------------------------------------|-----|--------------|------------------|-----------------|------|-----------------|-----|------|
|                                        |                       | Ca                                      | Mg  | Na+K         | HCO <sub>3</sub> | SO <sub>4</sub> | Cl   | NO <sub>3</sub> | B   | TDS  |
|                                        |                       | DEPTH                                   |     | 0-300 feet   |                  |                 |      |                 |     |      |
| 2N/22W-21D3                            | 6                     | 197                                     | 104 | 306          | 287              | 1054            | 156  | 34              | .96 | 2134 |
| 2N/23W-25H1                            | 2                     | 152                                     | 38  | 142          | 256              | 497             | 68   | 12              | .50 | 1114 |
| 25M1                                   | 3                     | 142                                     | 44  | 137          | 291              | 478             | 58   | 1.5             | .48 | 1150 |
| Average =                              |                       | 163                                     | 62  | 195          | 278              | 676             | 94   | 16              | .65 | 1467 |
|                                        |                       | DEPTH                                   |     | 300-700 feet |                  |                 |      |                 |     |      |
| 2N/22W-8R1                             | 1                     | 261                                     | 79  | 214          | 353              | 949             | 110  | 62              | .90 | 1894 |
| 9K2                                    | 1                     | 188                                     | 53  | 158          | 326              | 629             | 73   | 0               | .64 | 1228 |
| 9K3                                    | 4                     | 197                                     | 56  | 175          | 347              | 655             | 81   | 8               | .61 | 1519 |
| 10R2                                   | 1                     | 122                                     | 46  | 118          | 248              | 437             | 58   | 12              | .53 | 1014 |
| 16K1                                   | 21                    | 123                                     | 42  | 137          | 257              | 460             | 53   | 9               | .6  | 1081 |
| 16Q1                                   | 2                     | 202                                     | 67  | 139          | 320              | 651             | 86   | 28              | .74 | 1493 |
| 17Q1                                   | 7                     | 167                                     | 65  | 155          | 271              | 619             | 93   | 35              | .57 | 1406 |
| 19G1                                   | 1                     | 133                                     | 34  | 120          | 254              | 420             | 47   | 2.5             | .60 | 960  |
| 20M7                                   | 4                     | 130                                     | 42  | 131          | 231              | 477             | 57   | 4               | 1.5 | 1072 |
| 20Q1                                   | 22                    | 154                                     | 54  | 130          | 264              | 519             | 74   | 16              | .59 | 1201 |
| 2N/23W-23G1                            | 5                     | 123                                     | 40  | 112          | 243              | 404             | 51   | 0.1             | .44 | 973  |
| 24F1                                   | 2                     | 271                                     | 80  | 158          | 252              | 828             | 138  | 80              | .41 | 1807 |
| 36A1                                   | 1                     | 135                                     | 45  | 118          | 253              | 461             | 57   | —               | .60 | 1069 |
| Average =                              |                       | 169                                     | 54  | 142          | 278              | 578             | 75   | 21              | .67 | 1317 |
|                                        |                       | DEPTH                                   |     | > 700 feet   |                  |                 |      |                 |     |      |
| 2N/22W-10R1                            | 3                     | 128                                     | 36  | 150          | 271              | 473             | 57   | .17             | .52 | 1115 |
| 17Q4                                   | 1                     | 161                                     | 38  | 131          | 265              | 469             | 85   | 0               | .55 | 1120 |
| 20J1                                   | 8                     | 123                                     | 45  | 130          | 268              | 463             | 47   | 6.6             | —   | 1076 |
| 20L2                                   | 5                     | 132                                     | 47  | 139          | 273              | 505             | 52   | 4.7             | —   | 1153 |
| 2N/23W-5L1*                            | 7                     | 257                                     | 90  | 257          | 369              | 505             | 517  | 5               | .87 | 2000 |
| 5P1*                                   | 4                     | 450                                     | 112 | 325          | 323              | 524             | 1060 | 4.2             | .80 | 2798 |
| 10R1                                   | 6                     | 157                                     | 40  | 129          | 360              | 443             | 66   | 3.7             | —   | 1249 |
| 13F1                                   | 7                     | 140                                     | 47  | 159          | 349              | 485             | 71   | 2.5             | .66 | 1253 |
| 14K1                                   | 15                    | 143                                     | 43  | 155          | 382              | 419             | 68   | 0               | .6  | 1210 |
| 14L1                                   | 9                     | 155                                     | 45  | 153          | 465              | 450             | 75   | 1               | .56 | 1344 |
| 14M1                                   | 8                     | 150                                     | 50  | 167          | 365              | 511             | 74   | 1.2             | .66 | 1318 |
| 14N1                                   | 4                     | 163                                     | 46  | 173          | 388              | 534             | 75   | 4               | —   | 1383 |
| Average =                              |                       | 180                                     | 53  | 173          | 340              | 486             | 187  | 2.8             | .65 | 1419 |
| * Average with these 2 wells deleted = |                       |                                         |     |              |                  |                 |      |                 |     |      |
|                                        |                       | 145                                     | 43  | 149          | 339              | 480             | 67   | 2.4             | .61 | 1223 |

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## TABLE 3

## ANALYSES OF GROUND WATER IN SELECTED WELLS, 1970-1972

| WELL No. | NUMBER<br>OF ANALYSES | ION CONCENTRATIONS in parts per million |    |      |                  |                 |    |                 |   |     |
|----------|-----------------------|-----------------------------------------|----|------|------------------|-----------------|----|-----------------|---|-----|
|          |                       | Ca                                      | Mg | Na+K | HCO <sub>3</sub> | SO <sub>4</sub> | Cl | NO <sub>3</sub> | B | TDS |

DEPTH 0-300 feet

NO ANALYSES AVAILABLE

DEPTH 300-700 feet

|             |   |     |    |     |     |     |     |     |     |      |
|-------------|---|-----|----|-----|-----|-----|-----|-----|-----|------|
| 2N/22W-16K1 | 4 | 150 | 48 | 131 | 268 | 504 | 68  | 25  | .51 | 1144 |
| 17Q1        | 1 | 148 | 37 | 125 | 262 | 478 | 62  | 0   | .44 | 1101 |
| 19G1        | 1 | 124 | 45 | 115 | 251 | 436 | 52  | 0   | .67 | 970  |
| 20Q1        | 6 | 201 | 62 | 136 | 262 | 644 | 112 | 18  | .69 | 1383 |
| 20M7        | 1 | 129 | 43 | 119 | 259 | 444 | 49  | 1.0 | .60 | 983  |
| Average =   |   | 150 | 47 | 125 | 260 | 521 | 68  | 8.8 | .58 | 1116 |

DEPTH > 700 feet

|             |   |     |    |     |     |     |    |      |     |      |
|-------------|---|-----|----|-----|-----|-----|----|------|-----|------|
| 2N/22W-17Q4 | 1 | 150 | 44 | 135 | 223 | 497 | 67 | .58  | —   | 1125 |
| 20J1        | 9 | 136 | 44 | 102 | 245 | 453 | 48 | 2.3  | —   | 1039 |
| 20L2        | 9 | 139 | 45 | 118 | 254 | 426 | 55 | 1.5  | —   | 1085 |
| 2N/23W-13F1 | 1 | 146 | 42 | 149 | 364 | 438 | 62 | 3.1  | .57 | 1083 |
| 14K1        | 4 | 163 | 41 | 147 | 388 | 409 | 69 | —    | .62 | 1078 |
| Average =   |   | 146 | 43 | 130 | 295 | 456 | 60 | 1.87 | .59 | 1082 |



As shown on Table 3, the historical record for wells less than 300 feet deep is sparse but indicates exceptionally high concentrations of sulfate, chloride, nitrate, boron and total dissolved solids during all time periods considered. Most of the values are above Federal standards for domestic usage. The water is considered Class 3 for agricultural usage.

Water quality in wells 300-700 feet deep has been variable with time. During the periods 1940 thru 1959 they exhibit similar though slightly better quality than that in deeper wells, but since that time, their quality has been slightly poorer than that in the deeper wells. Water quality in 300-700 feet deep wells has been better since 1970 than during any other historic period. The general historic similarity in the quality between wells

300-700 feet and those greater than 700 deep helps confirm the idea that there is much vertical continuity between alluvial and San Pedro formation aquifers.

Quality in wells greater than 700 feet deep from 1950 to 1959 was inferior to that from 1940 to 1949. The period 1960 to 1969 exhibited better overall quality than any prior period. Data from 1970 to the present indicates that current quality is at its historic best. Nonetheless, sulfate (average 456 parts per million) and total dissolved solids (average 1082 parts per million) still remain quite high. Due to these concentrations, water in these deeper wells is presently marginal for domestic usage and considered as Class 2 for agricultural usage.

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By noting the location of individual wells it can be seen that there is a general increase in the concentration of most ions as one approaches the coast on the west and southwestern portions of Mound Basin. It is possible that water in the Oxnard and Mugu aquifers have been degraded somewhat in this area; due to hydraulic continuity with underlying strata, they have supplied some water to deep wells here which pump from San Pedro aquifers. Poor surface seals and extended gravel packs (particularly for City-owned wells at Pierpont Bay) could also allow inferior quality water into deeper zones. Reversed water level gradients noted on ground water contours for 1957 (Plate 8) occurred in this same area. Water quality in this area had become worse with chloride concentrations reaching maximum of about 100 parts per million by 1960-61 which concurs with the shift in City-pumpage from Pierpont Bay to the Golf Course area.

It should be noted in Table 3 that all four City-owned Golf Course Wells (2N/22W-20J1, 20L1, 20L2, and 20Q1) have been included in their appropriate depth category. These wells are not in the Mound Basin but were included in Table 3 for comparative purposes.

Water quality in wells 2N/23W-5L1, and 5P1 which are located near the mouth of the Ventura River diverges widely from the remainder of wells in their depth category during all time period considered. It is likely that improper well construction and/or well seals permit shallow degraded water to enter the well.

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For proper comparison, final averaging of constituent ions for their entire depth category was made both including and excluding these 2 wells.

From Table 3, it is seen the sulfate content of all wells exceed the recommended and/or mandatory limits for domestic usage. High sulfate content can arise in areas receiving little recharge or in those having only limited ground water movements. Certainly, actual amounts of recharge to Mound Basins are unknown, but the fact that there has been no long-term overdraft in the area suggests sufficient recharge. Limited ground water movement is likely in lenticular strata. Furthermore, water high in sodium-calcium sulfate and which often display high total dissolved solids is known to occur where basins are intersected by faults. Poor circulation could result in the structurally complex southern portion of Mound Basin.

Other ions of importance are calcium, iron, and manganese. The high concentrations of calcium in Mound Basin will result in hard water for domestic and industrial usage. Hardness, expressed as calcium carbonate, can be considered as very hard in the basin on the basis of a qualitative classification system suggested by U.S. Geological Survey. Water high in both calcium and sulfate will cause deposits and incrustations on well perforations.

Whenever present in ground water, iron and manganese typically occur together though the manganese is generally of less concentration. Water having greater than 0.3 ppm iron and

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greater than 0.05 ppm manganese will cause discoloration and precipitates in the water. In Mound Basin, concentrations of iron and manganese have attained concentrations as high as 1.7 and 0.4 ppm, respectively. Average values are somewhat less than half of these amounts. Iron and manganese generally occur in strata of marine origin.

Contours of total dissolved solids during the middle to late 1960's were prepared (Plate 11) to depict the recent overall water quality in the basin. To be noted is the general increase from 900 to about 1300 parts per million in a northerly direction across the basin. Wells in the central portion of the basin having similar depths as those to the south will reach stratigraphically higher aquifers in the San Pedro formation due to the north dip of the strata toward the axis of the syncline.

The water quality record in the vicinity of the proposed development is sparse. The only long-term record is from well 2N/22W-9K3, which produces water from Older alluvium and upper aquifers in the San Pedro formation. The water quality of this well is present in the following table:

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TABLE 4

WATER QUALITY

Well 2N/22W-9K3

| Date<br>Sampled | CONCENTRATION IN PARTS PER MILLION |    |     |                  |    |                 |                 |      | B    | F    | Fe    | Re-<br>marks      |
|-----------------|------------------------------------|----|-----|------------------|----|-----------------|-----------------|------|------|------|-------|-------------------|
|                 | Ca                                 | Mg | Na  | HCO <sub>3</sub> | Cl | SO <sub>4</sub> | NO <sub>3</sub> | TDS  |      |      |       |                   |
| 6/15/27         | 184                                | 49 | 141 | 305              | 78 | 584             |                 | 1343 | 0.55 |      |       |                   |
| 6/25/30         | 161                                | 49 | 121 | 355              | 70 | 454             |                 | 1210 | 0.41 |      |       |                   |
| 3/15/44         | 136                                | 37 | 117 | 342              | 56 | 395             | T               | 1103 | 0.51 |      |       |                   |
| 11/30/48        | 137                                | 41 | 114 | 345              | 56 | 391             | T               | 1093 | 0.45 |      |       |                   |
| 7/14/54         | 151                                | 40 | 112 | 338              | 63 | 422             |                 | 1126 | 0.74 | 0.33 |       |                   |
| 8/13/58         | 138                                | 57 | 125 | 350              | 65 | 451             |                 | 1186 | 0.49 | 0.60 | <0.10 |                   |
| 12/3/58         | 150                                | 51 | 132 | 352              | 67 | 449             |                 | 1201 | 0.53 | 0.60 | <0.10 |                   |
| 5/24/61         | 193                                | 58 | 157 | 337              | 81 | 620             | 7               | 1453 | 0.40 | 0.55 | <0.10 |                   |
| 3/24/62         | 211                                | 69 | 180 | 348              | 87 | 728             | 12              | 1521 | 0.50 | 0.50 | <0.10 |                   |
| 7/25/64         | 179                                | 51 | 176 | 350              | 78 | 602             | 6               | 1360 | 0.77 | 0.50 | <0.10 |                   |
| 7/31/69         | 206                                | 46 | 178 | 351              | 79 | 672             | 6               | 1510 | 0.76 | 0.60 | 0.36  | 0.42 <sup>m</sup> |

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As can be seen on Table 4 there has been a gradual and overall reduction in the water quality in this well from 1940 to 1969. Whether this trend has continued beyond 1970 and times of improved quality throughout the basin is unknown.

Also noticeable on Table 4 are the up and down fluctuations of quality during the different decade time periods as were in Table 3. These fluctuations can generally be correlated with variable climatic (precipitation) conditions which produced fluctuations in water levels in wells and in runoff (and recharge) from the Santa Clara River. Undoubtedly these latter fluctuations affected water quality between the different time periods. This is observable in Table 3 wherein these climatic fluctuations tended to mask quality differences between different depths of wells.

It is not the intent of this report to pinpoint exact sources of impairment to water quality in Mound Basin. General sources of degradation and pollutants would include citrus packing plants, oil field discharges, irrigation return water, and sewage treatment ponds. Improper construction, destruction and sealing of wells would allow these pollutants to enter wells.

There has been no observable and consistent indication of deterioration from sea-water intrusion in Mound Basin. Even during the drought and heavy pumping of the 1950's, when many wells had water levels below sea level, there was no prominent increase in salt content. Likely areas of possible initial intrusion would be along the southwestern and northwestern portions of the basin.

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## HISTORY AND PRESENT STATUS OF BASIN BOUNDARY DETERMINATION

Hydrologic Units and Subunits. To facilitate analysis of water supply problems, the California Department of Water Resources in 1953 divided Ventura County into various hydrologic units. Hydrologic unit boundaries were delineated principally by watershed and topography. Hydrologic units of importance to this study are the Santa Clara River Hydrologic Unit and the Ventura River Hydrologic Unit.

For more refined hydrologic analysis, the State further subdivided the hydrologic units into hydrologic subunits. Major subdivisions of the Ventura River Hydrologic Unit include the Lower Ventura River, Upper Ventura River, Ojai, and Upper Ojai subunits. Principal subdivisions of the Santa Clara River Hydrologic Unit include the Piru, Fillmore, Santa Paula, Oxnard Forebay (known also as Montalvo), Oxnard Plain, Pleasant Valley, and Mound subunits, the latter being of major importance to this study. (See Plate 12 - Hydrologic Subunit Areas).

Ground Water Basins. For the purpose of hydrogeologic analysis the Department of Water Resources delineated ground water basins within each hydrologic unit and subunit. Geology and geologic structure aided the determination of many of the ground water basin boundaries. The boundaries of these ground water basins differ somewhat from their comparable subunits. In this report only the boundary differences for the Mound area are of concern.

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Mound Ground Water Basin. The original Ventura County Investigation by the State Division of Water Resources in 1933 did not delineate a Mound Groundwater Basin. Instead, most of this area was included in a "Montalvo Basin".

The more thorough Ventura County Investigation by the State Department of Water Resources completed in 1953 re-defined and revised the ground water basin boundaries and identified the Mound Basin as a separate groundwater basin. Plate 13 - Mound Area, compares the boundaries of the Mound Ground Water Basin and the Mound Subunit of the Santa Clara River hydrologic unit as delineated by the State in 1953. As can be seen on Plate 13 the boundaries of the Mound Hydrologic Subunit are defined on the north, east and west by topography and/or physiographic features, and the Santa Clara River was selected as the south boundary. The north boundary of the Mound Basin as chosen by the State includes all permeable strata (San Pedro formation) that drain into the basin; hence this includes a small portion of the Lower Ventura River Subunit where these strata are also known to crop out. The east and west boundaries of the basin agree with those of the subunit area. The southern boundary of the Mound Basin was modified slightly and was chosen subparallel to the Santa Clara River.

Further minor modifications in ground water basin boundaries have been subsequently made by other investigators as the geology and geologic structure in these areas have become

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better understood. The boundaries of Mound Basin delineated by Dr. Mann in 1958 concur with those of the State except on the north side where Dr. Mann chose the base of the foothills as the boundary. The north boundary line is about 1 mile south of that delineated by the State.

Present Mound Ground Water Basin Boundaries. This investigation, in light of new geologic data, has necessarily redefined the boundaries of the Mound Ground Water Basin as defined by the Department of Water Resources. The following paragraphs define the basin boundaries for this report; except where indicated, they generally concur with those denoted by the State.

The north boundary extends to the northern limit of the exposures of permeable sediments (San Pedro formation) and, hence, includes those outcrops near the mouth of the Ventura River. The eastern boundary is formed principally by a fault-produced, ground water barrier (Country Club Fault) and partly by topography and drainage. The western boundary extends offshore to the submarine outcrops of the San Pedro formation, a distance of perhaps 5 to 6 miles from the mouth of the Santa Clara River, as indicated by recent geophysical data.

It is the southern boundary of the basin which differs from that denoted by the State. In this region, we believe that a boundary line based strictly on alluvial deposits does not exist between the Mound Basin and the Oxnard Forebay and Oxnard Plain basins to the south. Abundant lateral and vertical hydraulic continuity exists throughout these alluvial deposits and, hence, precludes a definite separation. However, based solely on the San Pedro formation, a boundary can be drawn.

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We have chosen a southern boundary based on the sub-alluvial outcrop of the San Pedro formation and its relationship to geologic structure (Montalvo anticline) in the area. Vertical continuity between the alluvium and San Pedro formation allows percolating water on the north limb of the anticline to be transmitted into ground water storage within the San Pedro aquifers in the Mound Basin. Similar water on the south limb of the fold is conveyed into storage in San Pedro aquifers in either the Oxnard Forebay or Oxnard Plain basins. The comparison between these boundaries and those indicated by <sup>the</sup> State are depicted on Plate 14.

### CONCLUSIONS

#### 1.10 GENERAL

It is hydrogeologically feasible to develop production water wells for the City of San Buenaventura in the Mound Basin. More specifically, the proposed development site near Victoria Avenue as delineated in the scope of this investigation appears hydrogeologically feasible.

#### 1.20 DATA

Water well and oil well data utilized for this investigation were obtained from local public agencies and individual oil companies. Due to geologic complexities and particularly to paucity of data in the immediate vicinity of the proposed development, available geologic and hydrogeologic data had to be projected. Nonetheless, the data were generally sufficient to determine locations for potential high-production water wells.

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### 1.30 MOUND BASIN BOUNDARIES

Historically, different boundaries have been used to delineate the Mound Ground Water Basin, principally along its southern edge. A southern boundary chosen on the basis of alluvial deposits has been shown to be unfeasible since alluvial aquifers are laterally continuous in this area. The southern boundary has been chosen herein to be the axis of the Montalvo anticline. Ground water percolating into the San Pedro formation on the north limb of this fold is transmitted into storage in the San Pedro formation within Mound Basin; ground water on the south limb is transmitted into San Pedro storage in either the Oxnard Forebay or Oxnard Plain basins.

### 1.40 GEOHYDROLOGY

Presently available data indicate that the Mound Basin's perennial yield (safe yield) is approximately 9,000 to 10,000 acre-feet per year. Extraction records during the period 1967 to 1971 show an average pumpage of 6,900 acre-feet per year from the basin. To date, there has been no historical long-term decline in water levels in the basin which would indicate overdraft.

### 1.50 GEOLOGY AND HYDROGEOLOGY

Table 5, which follows, summarizes the geologic and hydrogeologic conditions in Mound Basin.

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TABLE 5 - "GEOLOGIC - HYDROGEOLOGIC SUMMARY"

| Geologic Age        | Formation                        | Max. Thickness(ft.) | Generalized Geology                                                                                                                                                                                                                               | Generalized Hydrogeology                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------|----------------------------------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Recent              | Undifferentiated Recent Alluvium | 290                 | Unconsolidated, lenticular clays, silts, sands and gravels. Includes flood plain and active river deposits near Santa Clara River. Difficult to separate from underlying deposits.                                                                | Contains Oxnard aquifer at base. Formation not perforated by many wells in basin. Water quality variable and easily degraded. Water level contours suggest possible overdraft of formation in areas south of basin.                                                                                                                                                                                                                                                           |
| UNCONFORMITY        |                                  |                     |                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Pliocene            | Undifferentiated Older Alluvium  | 320                 | Unconsolidated clays, silts, sands and gravels. Includes Terrace Deposits near base of foothills. Part marine and part continentally deposited. Difficult to distinguish from underlying strata                                                   | Contains coarse-grained zone near base equivalent to Mugu aquifer in Oxnard Plain Basin. Most wells in basin contain perforations in the formation. Good hydraulic communication between overlying and underlying deposits. Water quality similar to that in San Pedro formation.                                                                                                                                                                                             |
| UNCONFORMITY        |                                  |                     |                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| San Pedro Formation | San Pedro Formation              | 2300                | Marine deposited, lenticular, poorly consolidated clay, sand and gravel. Lenticularity increases northward across basin. Outcrops and suballuvial exposures help define basin boundaries. Affected by structure and becomes thinner toward south. | Known from oil well data to contain Fox Canyon aquifer near base; no water wells in basin presently deep enough to penetrate it. Most wells perforating upper and middle portions of formation also contain perforations in Older Alluvium. Confinement of aquifers caused by impermeable strata in alluvial deposits. Base of formation is base of fresh water in basin and occurs at maximum depth of 2850 feet. Freshwater-saline water interface is 5 1/2 miles offshore. |

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TABLE 5 - (Continued)

|                                        |                                    |           |                                                                                                                                                       |                                                                                                                                                                                                                                                                               |
|----------------------------------------|------------------------------------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| er<br>leis-<br>ene<br>to<br>er<br>lio- | Santa<br>Barbara<br>Forma-<br>tion | 2500      | Marine deposited shale,<br>sandy shale and mud-<br>stone. Very difficult<br>to separate from under-<br>lying deposits without<br>paleontological data | Considered non-water-<br>bearing. Locally exhibits<br>fresh water on electric logs,<br>probably resulting from seep-<br>age from overlying San Pedro<br>formation. No evidence of<br>Grimes Canyon aquifer which<br>is known to be productive<br>several miles south of basin |
| lio-<br>e                              | Pico<br>Forma-<br>tion             | 12,000(?) | Marine deposited sand-<br>stone and interbedded<br>shale                                                                                              | Considered non-water-<br>bearing in basin though<br>strata yield some water<br>to wells in other por-<br>tions of Ventura County.                                                                                                                                             |

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## 1.60 STRUCTURE

Geologic structure in Mound Basin is very complex and present data are insufficient to accurately define it. Folding and faulting are prominent and result from severe compressional forces during the Middle Pleistocene.

Principal folds include the Santa Clara River syncline, the axis of which is subparallel to the Santa Paula Freeway, and the Montalvo anticline which forms the southern boundary of the basin.

Principal faults include the Pitas Point, the Country Club, the Oak Ridge and the McGrath faults. The Pitas Point fault is located near the base of the foothills on the north side of the basin; it correlates well with offshore geophysical data which have suggested very recent displacement. Little is known of its effect on ground water in Mound Basin.

The Country Club fault creates a marked ground water barrier and forms most of the east boundary of the basin. This fault inhibits ground water flow between the Mound and Santa Paula basins.

The McGrath and Oak Ridge faults are located in the structurally complex, southern portion of the basin; both faults are likely related to the same fault system. Neither fault apparently has severed hydraulic communication with the alluvial deposits.

## 1.70 GROUND WATER MOVEMENT AND WATER LEVELS

Recharge to Mound Basin comes from precipitation on

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the basin, influent seepage from the Santa Clara River, and inflow from Oxnard Forebay Basin and possibly Oxnard Plain Basin. Sufficient hydraulic communication exists between the alluvial deposits and underlying San Pedro formation to provide recharge into these deeper strata.

Ground water contours indicate a southerly direction of movement, conforming to the general topography of the basin. Water levels were near their historic high in the basin in 1944; many wells were flowing near the coast and along the Santa Clara River. Water levels in 1957 were near their basin lows, with many wells having levels below sea level. A local area of reversed gradient was present in Pierpont Bay on 1957 contours and probably resulted from overdraft of the Oxnard aquifer by pumpage from wells in the coastal plain. Present water levels are trending upwards toward their 1944 highs.

Ground water contours reveal the ground water barrier created by the Country Club fault; water levels are depressed in Mound Basin southwest of the fault relative to those in Santa Paula Basin to the northeast.

Ground water contours near the southern boundary of Mound Basin do not reveal any marked barrier effects indicating that the faults there do not completely sever hydraulic communication. This also suggests that the faults have not been active for a long time.

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Available well hydrographs suggest a gross confinement of aquifers in Mound Basin but, locally, vertical communication is known to exist. Cyclic water level changes generally conform to fluctuations in precipitation and variations in flow in the Santa Clara River. No long-term and continuous water level declines have been recorded which would indicate overdraft in the basin.

Recent geophysical data indicate that the fresh water-salt water interface is located  $5\frac{1}{2}$  miles offshore. Total ground water storage in the San Pedro formation extending to this interface should be substantial.

$Ca^{+}$   $Na^{+}$

Sulfate  
 $HCO_3^{-}$

#### 1.80 WATER QUALITY

Ground water in Mound Basin is characterized by having calcium and sodium as the major dissolved cations and sulfate and bicarbonate as the major dissolved anions. Total dissolved solids are generally high, and iron and manganese are present throughout the basin. These ions, together with high hardness, make the quality for domestic usage marginal. For irrigation usage the water is considered generally as Class 2.

Water quality in wells less than 300 feet deep exhibits very poor quality. Water quality in wells 300 to 700 feet deep and in wells greater than 700 feet deep has historically been grossly similar. Limited water

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analyses since 1970 have exhibited better overall quality than that in the preceding 30 years.

Similarity of water quality in wells of different depths suggests vertical continuity between aquifers in the alluvial and San Pedro deposits. Some masking of the uniqueness in the quality can be expected since each of the decade periods chosen for study purposes had numerous fluctuations in basin-wide water levels. Also, each period contained variations in flow in the Santa Clara River wherein runoff is known to be inversely proportional to concentration of total dissolved solids.

The concentrations of sulfate and total dissolved solids in the water exceed the recommended and/or mandatory limits for drinking purposes. Contours of total dissolved solids historically indicate a gradual increase northward across the basin. The water is generally hard and should be considered Class 2 for agricultural purposes.

Incrustation, probably from high concentrations of calcium and sulfate, currently plagues some wells in the basin. Wells owned by the City of San Buenaventura in the Municipal Golf Course are also plagued by this problem.

Due to the lenticularity of the San Pedro formation, it appears that not all strata have been completely flushed of their original connate waters. Some unknown portion of their high concentration of various ions, including iron and manganese, could be ascribed to wells producing from some of these zones. Other sources of impairment in the

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basin would be agricultural and industrial pollutants. Improper well construction and poor well seals also enable degraded waters to enter wells.

To date, there is no definite evidence that sea-water intrusion has occurred historically or that it is occurring presently in Mound Basin. Any intrusion would initially degrade the alluvial aquifers. A landward gradient was present in Pierpont Bay in 1957. Concentrations of the chloride ion increased to a maximum of 100 parts per million in a few wells. Vertical communication between all aquifer systems coupled with improper well seals and/or over-extended gravel envelopes would permit water of inferior quality into lower aquifers. Hence, the reversed gradient may be a reflection of overdraft and subsequent degradation within the Oxnard and possibly the Mugu aquifers. The reversed gradient continued to 1960-61 which corresponds to a shift in City-pumpage from Pierpont Bay to the Municipal Golf Course.

Complete analysis of basin-wide water quality and predictions of quality in future wells is unfeasible at this time due to paucity of data and poor well control. Most wells are perforated in many aquifer zones while other wells lack surface seals; many wells lack data on perforated intervals.

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1.90 AREAS OF POTENTIAL WELL DRILLING

In order to graphically present our conclusions for potential locations of production water wells, Plate 15 - Potential Water Well Locations, has been included. The presentation of Plate 15 should not be construed to mean that production water wells cannot be obtained outside of the areas shown. The areas represent the combination of hydrogeology, water quality, water level dynamic, and proximity to the proposed area of development which we believe offer the most favorable locations for additional water supply to the City of San Buenaventura. The locations have been numbered consecutively in the order of potential they represent. Properly designed wells in these area should provide the required 2,400 gallons per minute supply as discussed in the scope of this report. The new wells should also be sand free. Exact water quality at each location must be determined at the time of exploratory drilling.

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## RECOMMENDATIONS

### 2.10 WELL LOCATIONS

- 2.11 General. Four water well locations are recommended. Some latitude can be used in the locations of the wells in order to coordinate with the City's water distribution system and the proposed underground water storage facility so long as the locations fall within the areas noted on Plate 15.

Table 6 below summarizes geologic and hydrogeologic conditions which are anticipated at each proposed well location based upon projections of existing data.

To reach depths corresponding to the base of the San Pedro formation as indicated in Table 6 will require the use of rotary drilling equipment. Recommendations for an exploratory drill hole are found in Section 3.10 Recommendations. Specifications for future test holes are presented in Appendix B . Cost estimate data for various phases of exploratory and production hole drilling and completion are presented in Appendix C.

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TABLE 6 "ANTICIPATED CONDITIONS AT RECOMMENDED WELL LOCATIONS"

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| Well Location                | Depth to Geologic Contacts<br>Base of Older Alluvium      Base of San Pedro Fm. |           | Depth to Fox Canyon aquifer zone | Maximum Historic Water Level Fluctuations | Anticipated Water Quality | Remarks                                                                                                                                                                                                          |
|------------------------------|---------------------------------------------------------------------------------|-----------|----------------------------------|-------------------------------------------|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| # 1<br>Victoria & SP Fwy.    | 450 feet                                                                        | 2850 feet | 2250 to 2550 feet                | 35 feet                                   | 1100-1300 ppm TDS         | Well site conditions require casing off Oxnard and Mugu aquifers. Site requires line $\frac{1}{2}$ mile long to reach new reservoir.                                                                             |
| # 2<br>Victoria & Loma Vista | 320 feet                                                                        | 2780 feet | 2080 to 2380 feet                | 50 feet                                   | 1100-1400 ppm TDS         | Site is adjacent to new reservoir. well site conditions require casing off of alluvial aquifers and a few in upper San Pedro formation Fox Canyon zone probably more lenticular here than at any other location. |
| # 3<br>Hwy. 101 & SP Fwy     | 600 feet                                                                        | 2600 feet | 2100 to 2400 feet                | 50 feet                                   | 1100-1300 ppm TDS         | Site in between present plant and new reservoir. Conditions may permit perforations in Mugu aquifer                                                                                                              |
| # 4<br>Pierpont Rav          | 550 feet                                                                        | 2600 feet | 2050 to 2350 feet                | 60                                        | 1000-1200 ppm TDS         | Near Pierpont well Can tie pumpage to pres. system. Sea water intrusion would occur here                                                                                                                         |



2.12      Location One. We recommend that the Victoria Avenue-Santa Paula Freeway site be used to initiate the well drilling program. It is a good starting point to delineate deep water-boring zones, heretofore unexplored in the area, and hence to supply invaluable hydrogeologic data on these deep aquifers. Geologic data, and water quality and water level information obtained at this site would supplant data which necessarily had to be projected into other recommended areas.

We recommended that this first exploratory hole be drilled deep enough to penetrate 100 to 200 feet of shale in the upper portion of the Santa Barbara formation. This will define the base of fresh water in the basin, heretofore unknown in this area, and hence insure that all potential water bearing zones in the San Pedro formation have been located and defined.

2.13      Location Two. This site is located adjacent to the proposed reservoir at Victoria Avenue and Loma Vista Road. It should be noted that available data had to be projected further to reach this location than any other recommended site.

2.14      Location Three. This location is just south of U.S. Highway 101 near its intersection with the Santa Paula Freeway. This is the only site where hydrogeologic conditions will readily allow perforations in the Mugu aquifer.

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This site is located about 8,500 feet, measured along a straight line, from both the Pierpont Bay treatment plant and newly proposed reservoir.

- 2.15 Location Four. This site is at Pierpont Bay where the City previously had pumping wells. Verification of proper abandonment of these prior wells is important if this site is used. The City's present treatment plant and water distribution system is adjacent to this site.

This site would be degraded by salt water intrusion through alluvial aquifers long before similar conditions could arise in other recommended sites.

- 3.10 EXPLORATORY DRILL HOLE

<sup>information regarding</sup>  
To provide/the actual geologic and hydrogeologic conditions and to provide design parameters for a final production well, we recommend drilling a 10 to 12-inch diameter exploratory test hole as an initial step at any site chosen. Standard rotary drilling methods will be required.

- 4.10 WELL SPECIFICATIONS

Detailed well specifications are presented in Appendix B to this report. In general, the specifications were developed by assuming that an initial 3,000 foot deep exploratory boring would be drilled on the Victoria Avenue-Santa Paula Freeway site. Once having defined the base of the San Pedro formation aquifers, any other locations in the future would necessitate only 2,700 feet deep borings.

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Samples of the materials encountered should be collected and a geologic log prepared. A portion of the samples should be examined paleontologically to determine age and formation equivalents. The pilot boring should be electric logged to delineate potential aquifers. A continuous clip meter survey should be made to determine bedding attitudes.

Important aquifers should then be independently developed and tested for yield and water quality utilizing a submersible pump and properly placed well screens and inflatable packers.

From the data acquired, a final production well can be properly designed to provide the required 2,400 gallons per minute supply. At this point, two directions could be followed. The 3,000-foot deep boring could be backfilled and abandoned, or it could be reamed and salvaged for use as the production hole. Cost estimates presented in Appendix

C have assumed that the exploratory boring would be abandoned.

We have assumed that several hundred feet of potential water-bearing sands will be encountered by the well. For optimum results under the artesian conditions known to exist,

it will require that about 75 percent of the aquifer thickness be screened. Twelve-inch diameter well screen will be sufficient to produce 2400 gallons per minute utilizing an entrance velocity of 0.1 feet per second for water entering the screen. Optimum outside diameters of well casing between 22 and 24 inches will be required

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to produce the anticipated supply. Pump bowls, 16 inches in diameter, will be necessary to deliver this quantity to the ground surface.

We have anticipated 100 feet of drawdown at production capacity based on a conservative specific capacity and assumed friction losses. Since Locations One and Two have similar surface elevations of approximately 250 feet above sea level, and the basin's low static water level in these areas is near +10 feet elevation, we will assume that the pump is set near the 400-foot depth level. This will necessitate 400 feet of 24-inch diameter casing. Present well sealing standards will require a 30-inch diameter hole and proper cement seals near the surface and adjacent to alluvial aquifers as presented in Department of Water Resources Bulletin 74-9 published in 1968.

Since Locations Three and Four have similar elevations of about +50 feet and the basin's low water level is near -40 feet elevation, we will assume that the pump is set near the 200-foot depth level. This will require 200 feet of 24-inch diameter casing.

Below the bottom of the casing, based on field conditions, a decision can be made to reduce its diameter nearer that of the well screen to facilitate certain economic and weight economies in the final well at any location.

We have recommended using wire-round stainless steel continuous slot well screens for estimating purposes.

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However, water quality analysis (particularly the Ryznar Stability Index) may permit more economical types of casing. It is estimated that about 75 per cent of each important aquifer will require screening, with blank casing in the remainder of the hole.

All of the wells should be gravel packed. A designed gravel pack is required in the sediments due to anticipated variability of the grain sizes in the aquifer zones. Proper gradation of the gravel packs will be determined from grain size analyses of materials encountered during drilling. It is anticipated that the properly designed and constructed well will not produce sand. Cost estimates, presented in Appendix C, were based upon unit values and assumed unit requirements.

#### 4.11 FINAL PRODUCTION WELL

The final production hole will be designed to yield a 2400 gallons per minute supply. Original test pumping of the well and aquifers will undoubtedly reveal that maximum well capacity is perhaps 3000 to 3500 gallons per minute. For maximum well service life and to minimize sand channeling thru the gravel pack, we recommend that the final well not be pumped in excess of its original 2400 gallon per minute design capacity.

For the final well, we also recommend that a program of periodic surveillance of production and static and pumping levels be maintained. Graphs of these data versus time will quickly denote any possible problems such as incrustation or corrosion which can then be repaired in their initial stages.

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#### 5.10 FUTURE DATA COLLECTION

Based on our review of available water quality, water level, and water supply data in Mound Basin, it is apparent that there are numerous gaps both in time and area. Previous data collection has generally been haphazard and non-systematic.

We recommend a systematic upgrading of available data. Data can be computerized and put on easily retrievable print-out sheets for future reference.

Locations and ownership of all individual wells should be verified. Well references should be made to the system based only on the Federal Land Survey (Appendix A). Wells shown on present maps should be checked for activity; many are known to have been destroyed. For those that are active, accurate geologic and electric logs (if available) should be obtained. Those logs not already on file may possibly be in the possession of the well owner. An attempt should be made to obtain total depths and perforated zones in each well.

Once the above data have been acquired, a system of key wells can be delineated in the basin. Key wells can be chosen on the basis of (1) various locations in the basin, (2) penetration to various aquifers, (3) quality and quantity of data available for each well.

Key wells should be periodically monitored. Initially, each well should be sounded for total depth and static water level. The well should then be test pumped for a

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few hours to determine discharge and pumping level (draw-down), and a water sample taken for quality analysis in the City's laboratory. Once these initial data are on file, it can be repeated once every 12 to 16 months.

Water levels in the wells should be monitored more frequently. Yearly basin highs and lows are best determined if the wells are measured in the spring (March-April) and in the fall (September-October), respectively.

Water quality samples should be taken only after the well has been pumping several hours. Optimum conditions for sampling are during that time of the year when the well is in active use, probably during the summer months.

The first water analyses should be a "complete" one to indicate overall quality. Yearly samples taken thereafter can be "partials" which would denote any possible changes.

Meetings with Ventura County Flood Control District and United Water Conservation District should be conducted to discuss areas in Mound Basin which presently lack data and those areas which are actively monitored by these agencies. Those key wells that are not and will not be monitored by these other agencies can be checked by City personnel.

The attachments which complete this report are listed in the Table of Contents.

Respectfully submitted,  
GEOTECHNICAL CONSULTANTS, INC.

Joseph M. Gonzalez  
President

RS:JMG/ep.

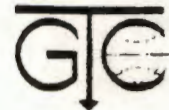
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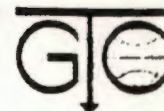
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# LOCATION MAP