Monterey County
Board of Supervisors
P. O. Box 1819
Salinas, Ca. 93902

Subject: Hydrogeological Report on the Deep Aquifer, Salinas Valley, Monterey County, California

Honorable Boa/rd of Supervisors:

Transmitted herewith are 10 copies of the above report as called for under contract between Thorup and the Board dated August 3, 1976.

This report is updated to include pertinent groundwater developments in the Deep Zone subsequent to the drilling of the County Well near Mulligan Hill in 1976.

The subsequent pumping history and water quality data of the County Well, and the data from three additional wells completed in the Deep Zone confirm this aquifer as a viable source of groundwater in the range of Class 1 and the upper part of Class 2 types as defined by the State and County Health Departments. Deep Zone pumpage at this time is being used for municipal purposes in Marina, for the Monterey Dunes Subdivision and for irrigation purposes at the County and P G & E Wells.

Inasmuch as the locations of the four wells are near the shoreline of Monterey Bay, some concern has been voiced on the possibility of salt water intrusion into the Deep Zone. Flood Cotnrol will be conducting some tests to help identify the amount of safe yield which may be extracted from the aquifer.

I trust this report will assist in further exploitation and evaluation of the Deep Zone and that the zone will become a valuable source of groundwater for the valley in the future.

Very truly yours,

RICHARD R. THORUP

ABSTRACT

During 1976, in response to a need for a new supply of fresh water for irrigation lands in the Castroville Area, the County of Monterey Board of Supervisors authorized the County Flood Control and Water Conservation District to embark on a program to develop, if possible, a supply of fresh water from a potential fresh water aquifer lying below the salt water-intruded 180 and 400 Foot Zone Aquifers. This aquifer is known as the Deep Zone, formerly called the 900 Foot Aquifer. The County Well was successfully completed in the Fall of 1976 as an artesian well thru perforations between 880 and 1560 feet. On a 48 hour pump test the well produced 2000 gpm of Class 1 groundwater from a pumping level of 163 feet. The well is in Section 6, T14S, R2E, on the north side of the Salinas River about 1/2 mile east of the Monterey Bay shoreline. The well was subsequently turned over to the landowners and is now being used to irrigate 549 acres of crops.

Three additional wells have since been drilled into the Deep Zone, the last one by the City of Marina. This well produces 2000 gpm of Class 1 groundwater from an interval similar to the County Well.

Drilling records of abandoned oil test wells show that the Deep Zone extends along the coast between Marina and the Springfield-Moro Cojo District, north of Moss Landing, for a lateral distance of 12 miles. It is believed to extend into the Soquel-Aptos area, near Santa Cruz and to Seaside on the south. The zone extends in the subsurface along the Salinas Valley southeasterly to San Ardo, where it is called the Paso Robles formation. The zone is thought to outcrop along the walls of Monterey Canyon in Monterey Bay at a distance of some five miles from the shoreline.

The thickness of the zone varies from 700 feet in the County Well to a maximum thickness of 2000 feet west of Greenfield. South of King City, along the valley floor, the formation thins to a a few hundred feet, where it rests on Pliocene and Miocene Strata.

The Deep Zone along the coast lies above Miocene Marine Shale. It is the lowermost fresh-water bearing aquifer in this District. The lower 350 feet are composed of 3 weakly indurated fossilifirous sand fingers separated by 20 foot layers of clayshale. These marine strata are correlated with the Pliocene Purisima formation of the Santa Cruz Mountains. The saline waters of these marine beds were flushed out in Pliocene and Pleistocene time and replaced by fresh water. The marine strata grade laterally eastwards into the Non Marine Paso Robles Sands, gravels and clays a few miles east of the coast. At the Marihart abandoned oil test well in Section 31, T15S, R4E, near Chualar, the strata are all non marine. The formation is buried along the east side of the Salinas Valley to Cholane Creek. South of this point it crops out along the base of the hills to San Lucas. On the south and west sides of the valley, the formation outcrops over portions of Fort Ord and the Spreckels Hills; along the east flank of

the Sierra de Salinas the Paso Robles appears in isolated outcrops dipping into the valley. Most of the formation in this strip is covered by alluvial fans. The formation reappears at the Arroyo Seco River and forms a fairly continuous line of outcrops southwards to King City. The formation outcrops along the westerly edge of the Salinas River, and in a strip along the edge of the hills, between King City and San Ardo.

Fourteen wells, stretching between the Prunedale Hills and King City, have been perforated solely in the Deep Zone. In all of the wells the quality of the wter is either Class I or in the higher quality level of Class II. Thirty additional wells mostly in the northern end of the valley, are dual perforated in the upper member of the Deep Zone and the 400 Foot Aquifer.

Total groundwater in storage is calculated at 1,340,955 acre feet within the political boundary of the Castroville Irrigation Project. Total groundwater in storage within this study area is 21,525,610 acre feet. Because of the unknown location of the salt water-fresh water interface beneath the bay, no figure for usable groundwater, or safe yield, in the coastal area is estimated at this time. Additinal testing of the County Well and the drilling and testing of new wells in the Deep Zone, together with constant monitoring of the quality and water level of the present wells, will hopefully provide, in time, sufficient data to provide a meaningful answer to this important question.

Usable groundwater in areas removed from the coast (Areas 2, 5, and 6 in this report) is calculated to be approximately 3,700,000 acre feet.

Average annual recharge into the Deep Zone is calculated at _____ acre feet. This recharge begins near the Salinas Valley town of San Ardo, 73 miles from the Monterey Bay shoreline by 65,500 acre feet percolation from the Salinas River thru the alluvial sands and gravels into the underlying coarse sediments of the Paso Robles formation, and from direct percolation into the Paso Robles outcrops. Northwards towards the bay, recharge along the east side is generated by small stream inflow into terraces and alluvial fans and downwards into the underlying Paso Robles sediments. Direct precipitation into Paso Robles outcrops occurs along the western edge of the valley from San Ardo to the Fort Ord Military Reservation. Subsurface percolation thru the porous Aromas formation into the underlying Paso Robles occurs in the Military Reservation, Marina, and the Prunedale Hills. Most of the Deep Zone recharge is thought to be derived from Salinas River percolation between San Ardo and Soledad.

DEVELOPMENT HISTORY AND REGIONAL HYDROGEOLOGICAL STUDY OF THE DEEP ZONE PLIOCENE AQUIFER NEAR MOUTH OF SALINAS RIVER

Introduction

The Monterey County Flood Control and Water Conservation District (M.C.F.C.), in early 1976, through funds authorized by the Board of Supervisors, drilled and completed a successful irrigation water well exclusively in the Deep Zone. The well was drilled on land lying within the Castroville Irrigation Project and is located on the north side of the Salinas River one-half mile east of Monterey Bay, near the topographic landmark of Mulligan Hill.

The purpose in drilling the well at this location was to establish the viability of providing Class 1 groundwater from the deep zone for irrigation in the Castroville area. The need for Class 1 water had become acute over the last 20 years upon the progressive encroachment of sea water intrusion, first in the 180 foot aquifer and, subsequently, in the underlying 400 foot aqufier.

The Castroville area, which has been a part of Zones 2 and 2A since their inception, has benefitted form the consturction of the Nacimiento and San Antonio Dams in South County by receiving constant percolation of resh water into the alluvial aquifers from flow from the dams, but the benefit to this district has been insufficient to halt the intrusion. Therefore, the decision was made, and the funds authorized, to; first, drill a test hole to the base of the deep zone and analyze the results, and, second, depending upon the results of the test hole, to drill and complete an irrigation well. In 1976, the Fontes test hole was drilled with the goal in mind of a potential pumping rate of 3000 gpm, which, in the opinion of the engineers, would justify the establishment of a well field which would meet the Bureau of Reclamation Fund Application PL 984 requriement of a guaranteed supply of 18,000 acre feet per year. This was the amount deemed to be needed during anticipated forthcoming dry periods.

The Fontes location did not appear to be capable of meeting this requirement, so the decision was made to drill the Well No. 1 at Mulligan Hill. This well was completed and test pumped in December 1976. It pumped 2000 gpm at 163 feet of Class 1 water, from a perforated interval of 880-1560 feet.

Three additional deep, successful wells have been drilled in the intervening years and have established the viability of the zone along the coast. These wells extend from abut a mile south of Moss Landing, on the north, to Marina, on the south, a distance of 7.5 miles. Indications form electric and drillers logs of oil test wells drilled in the Moss Landing and Springfield-Moro Cojo districts are that fresh water in this zone extends northwards along the coast towards the Pajaro River, and south into the Fort Ord area.

Southeast, toward the valley towns of Greenfield and King City, a distance of some 60 miles from Moss Landing, indications are that the deep zone continues up the Salinas Valley beneath the valley alluvium in sufficient thickness and permeability to be a continuous viable aquifer. It is a repository for several million acre feet of groundwater beneath the shallow alluvial sands and gravels, now the sole source of gorundwater.

Reference is a preliminary report by this author containing a detailed account of the results of the MCFC Fontes test hole. The report includes a structure contour map and isopach map of the deep zone, a map showing the recharge areas, and six cross-sections across the Salinas Valley between Moss Landing and King City. It also contains a description and history of the Castroville Irrigation Project and a map showing the hydrologic provinces in the Salinas Valley.

This present report is concerned primarily with (1) the geological and well development results of the MCFC well No. 1; (2) a refinement of the stratigraphy of the deep zone along the coastal area with a series of 8 electric log cross-sections covering the northern part of the Salinas Valley; (3) 5 updated cross-sections between Spreckels and King City; (4) updated structural contour map; (5) isopach map and (6) recharge map; and (7) a water quality and groundwater storage map. The investigation was enlarged to include the Prunedale Hills and adjoining Springfield District, north of Moss Landing, and a portion of Fort Ord, along the southerly edge of the original report.

For additional background information on the Castroville Irrigaiton Project and the Salinas Valley hydrologic provinces, consult Reference 34.

<u>Illustrations</u>

<u>Plate 1</u> - Geologic Mpa, Cross Section Lines and Selected Well Lists

The Geologic Base Map for this study is a strip map covering the area between the Pajaro River, on the north, to King City on the south, the Gabilan Range in the east, and the Carmel Valley on the west. The westerly limit of the drainage basin is the easterly slope of Sierra de Salinas. The original scale is 1:125,000. Most of the geology was taken from Dibble's USGS open file quadrangel maps with a few revisions by the present author. The Plate contains one table with 44 numbered oil test wells and another with 37 water wells which were used in the construction of the various plates. This Plate also shows the location of Cross-Section lines A-A' thru G-G' and I-I' thru M-M'.

Plate 2 - Is a Structural Contour Map on the base of the Deep Zone.

The limits of the basin extend between Springfield-Moro Cojo, on the north, to King City at the southeast. Tables 3 and 4 contain the control points (subsea) used in the construction of the map. The buried easterly subsurface limit of the Paso Robles formation, as is presently known, is shown, as is the direction of groundwater flow.

Plate 3 - Is an Isopach Mpa of the net sand thickness (clays and sand clays excluded) of the Deep Zone.

The thickness along the Salinas River between Greenfield and Monterey Bay is estimated from well and outcrop data to be in excess of 500 feet.

Plate 4 - Groundwater Storage Basins and Water Quality Chart

This Plate divides the total area into 6 separate groundwater basins:

1) Castroville Irrigation Project
2) Prunedale Hills
3) Springfield-Moro Cojo District
4) Marina - Fort Ord East Garrison
5) Central Salinas Valley
6) East Side

Table 5 shows the surface area of each basin and the calculated amount of storage in acre feet and the estimated amount of useable groundwater in storage for each basin. The areas were planimetered by Flood Control personnel.

Water Quality Chart shows selected quality data on 14 wells perforated only in the Deep Zone.

Values are shown for EC, CL, and Na.

Plate 4A

This plate shows 13 Recharge Areas located between Springfield-Moro Cojo, at the Northwest, to San Ardo, at the Southeast, a distance of 79 miles. Areas 1, 2, 3, 4 and 5 are in the hills along the westerly border of the valley; Areas 6, 7, 8, 9 flank the easterly edge of the valley; Areas 10, 11, 12 and 13 are segments of the valley floor between San Ardo and Spreckels.

Total recharge from the 13 areas is estimated to be 50,000 + acre feet per year. This recharge is believed to percolate within the Paso Robles formation from the San Ardo downslope into Monterey Bay.

Plate 5 - Regional Cross-Sections

1) A longitudinal section (A-A') between the Monterey Submarine Canyon, on the north, and King City, on the south, a distance of 60 miles.

2) Six Transverse Sections (B-B' thru G-G')

Plate 6 - Coastal Cross Section I-I'

This north-south cross section correlates the Deep Zone between Seaside, on the south, to the Springfield-Moro Cojo District, three miles north of Moss Landing, on the north, a total distance of 19 miles. Data from 19 wells (5 abandoned oil test wells and 14 water wells) is incorporated in this section.

Plate 7 - Cross Section J-J'

This is a SW-NE cross section extends from the Flood Control well (14/2/6L1) to a water well in easterly Prunedale Hills, which bottomed in weathered granite basement at 530 feet. Included is the Fred Ash abandoned oil-test well in easterly Prunedale Hills drilled to 2898 feet in sedimentary strata of unknown age. The electric log was run only to 1961 feet. Electric logs were used for correlation between wells.

Plate 8 - Cross-Section K-K'

This is an east-west cross section using electric logs thru 6 wells. It extends from Moss Landing (west) to a point near the intersection of Meridian Road and Highway 156 (east). The deep zone was penetrated only at Moss Landing in an abandoned oil test well (No. 7).

Plate 9 - Cross-Sectin L-L'

This is an east-west cross-section extending from the Flood Control well, near the coast, across the basin thru Salinas and the Alisal District to the Gabilan Range. Seven electric logs and one driller's log were used. This section shows the grading of the Salinas River deposits into the alluvial sands. The Alisal Fauklt is shown to offset basement.

Plate 10 - Cross-Section M-M'

This is a north-south section between Moss Landing, on the north, and the new City of Marina deep well on the south. Electric logs from 10 wells were used.

This cross-section duplicates a portion of Cross-Section I-I' (Plate 6) but was included in order to show the electric log correlations in the Deep Zone at a larger scale. Water quality is best in Well No. 37 and poorest in Well No. 6.

GEOLOGIC SETTING

The Salinas Valley deep aquifer consists primarily of sands and gravels of the non-marine Pliocene Paso Robles Formation which, upon grading into marine sands and gravels along the Monterey Bay shoreline, are correlated with.

The Paso Robles strata were laid down by the ancestral Salinas River which had its headwaters in the upper Salinas Valley and the Paso Robles area, from which it transported the sediments along the Salinas Valley into Monterey Bay. Minor oscillations of sea level produced an interbedding of marine and non-marine environments along the shoreline of the bay.

From King City to Salinas, west of Highway 101, the strata are all non-marine fluvial deposits consisting of interbedded sands, gravels, and clays. About a half-mile east of the highway, the Paso Robles interfingers with alluvial fan deposits, which carry a fairly high percentage of clay and an overall lower permeability. The thickness of the fan material is 700-800 feet, underneath which Paso Robles strata occur along the westerly edge of the fans.

Between the Salinas River and the Sierra de Salinas, from Spreckels to Greenfield, fan deposits spread easterly from the foot of the range to the river. Sparse outcrops of Paso Robles are visible along the east side of the trace of the Reliz-Rinconada Fault, where they have been elevated by the action of the fault. It seems reasonable to postulate that the Paso Robles underlies the entire strip of fans. Two test holes, one in Sect. 12/17S/4E and the second in Sec. 12/18S/5E were abandoned at 500 feet in fan material, which the drillers locally call "hill formation". Two water wells west of the River Road, opposite Gonzales, at surface elevations around a hundred feet above the valley, encountered 50 feet of loose sand and boulders bottomed by 20 feet of clay below alluvial fan material at drilled depths below 500 feet. The lack of cementation, as described, suggests alluvial rather than Paso Robles material. Drilling was not deep enough in either of the wells to determine whether or not fan material is present below the gravels.

The regional cross-sections (Plate 5) picture the Reliz-Rinconado Fault as being a thrust fault with an offset of several thousand feet.

Monterey Bay

Greene (Reference 18) has identified a series of sedimentary strata in Monterey Bay extending from Middle Miocene to Recent in age. Along the coastline, south of Moss Landing, the combined thickness is 4000 feet thick, of which approximately 1500 feet are of Pliocene and Pleistocene age, and the underlying 2500 feet are Miocene shale with a minor amount of interbedded sand.

The strata along the coastline are only gently folded and seemingly uncut by major faulting. Farther out in the bay the shales are folded and faulted along the Monterey Bay Fault Zone, which treads across the bay in a northwest-southwest direction.

Along the slides of the Monterey submarine canyon, which traverses westerly from Moss Landing, the Pliocene strata outcrop along the canyon walls and are thought to be subject to invasion of saline waters. Slumping and landslides occur on a rather large scale along the canyon walls. This may or may not enhance seawater intrusion.

Greene indicates that the Pliocene slopes toward MontereyCanyon from the coastline at a low angle.

NORTHERN SALINAS VALLEY

Fresh water-bearing strata underlying the Salinas Valley are found in three aquifers. The upper two are the 180 foot and 400 foot alluvial aquifers, composed of unconsolidated boulder and gravel beds, mixed with sand and clay streaks. Indidivual gravel bodies up to 100 feet thick occur. The aquifers often contain more than one gravel bed, with 10 foot clay separations. These alluvial aquifers extend the length of the Salinas Valley, unconfined in south county and confined from Gonzales north. The bulk of these gravel beds extend laterally between Highway 101 and River Road, a distance of about three miles. Farther northwest, at about Highway 68, south of Salinas, the deposits fan out and cover the area along the coast between Marina, on the suoth, and the Springfield District on the north, a lateral distance of 12 miles. They undoubtedly exist beneath the coastal waters of Monterey Bay. REd sand and red sandy clay of the Pleistocene Aromas formation is found below the 400 foot aquifer in 6 wells along the coast thus fixing the stratigraphic position of the 400 foot aquifer as being within the time boundary of the Aromas formation. The 1976 Report of this author (Reference 33) erroneously placed the 400 foot aquifer in the Paso Robles formation.

The third aquifer is the deep aquifer, or the 900 foot aquifer, as it was referred to in Reference 34. This aquifer is Pliocene in age. It is composed of sands, gravels and clays of the Paso Robles formation. In south county, the base is picked at the base of the high resistivity kicks on the electric logs. In north county, the base is picked at the base of the Pliocene sands, which in this part of the valley rest unconformable on the Miocene Monterey shale formation. The lower 400 feet of these sands is correlated with the Purisima of Watsonville - Aptos and the Santa Cruz Mountains Purisima. Electric log correlations place the strata below lower member the top of the Flood Control well as being equivalent to Purisima member B int he Aptos area as defined by Hickey (Reference 22). The base of the deep aquifer at Mulligan Hill at 1600 feet is equivalent to the base of the high resistivity kicks int he Paso Robles in central and south county. The boundary of the transition of these lower strata from marine to non-marine towards the east is not precisely known because of a lack of deep well data, but is believed at this time to lay in a north-south line east of the Flood Control Fontes test hole, in the vicinity of Davis Road, or perhaps as far east as Highway 68.

The name "900 foot zone" is being replaced in this report by the name "Deep Zone", as it is felt that the term "900 foot zone" is too restrictive in meaning. For one thing, it infers by implication a reasonably thick aquifer at 900 feet, which is not the case. It fails to communicate the fact that most of the sand is deeper than 1000 feet. And thirdly, the top of the zone isnot at 900 foot. The top of the Deep Aquifer is, in fact, the top of the Paso Robles formation, which is closer to 700 feet than it is to 900 feet.

CENTRAL VALLEY

Between Spence and Soiledad, the top of the Deep Zone is placed at the base of the 400 foot zone, considered to be at 600 feet, as for example in the Marihart Well (Plate 1, Table 1, Well No. 13), near the S. P. R. R. siding at Spence. Coarse sands and gravels, with interbedded tan clay streaks, continued down to a depth of 1630 feet, the interval 1180-1550 being predominantly coarse to pebbly, with minor greenish-black and blue-green sand. The interval 1630-1720 contains streaks of fine to medium sand. At 1720 the lithology changes to predominantly clay and medium-gray sandy siltstone with interbedded sand streaks. The beds from 1630 to 1720 are considered to be transitional between the sand and gravel above, and the clay and siltstone below.

A well field near this well was recommended by this author in 1976 (Refrence 34) because of the large amount of coarse material present in this locale. Well No. 14 (Plate 1, Chart 1) was drilled in 1980 by Texaco, Inc. to 2306 feet. It is located on an alluvial fan 1 mile northwest of Gonzales. SAnds and gravels premoniate between 685 and 1090, below which the material becomes thin bedded with low permeability. A prominent elog break at 1490 is taken as the base of the deep zone. Granite basement was encountered at 1975 feet. The lower par tof the Deep Zone, unlike the Marihart well, appears to lack coarse sand and gravel. These are believed to lie to the west, toward Highway 101.

SOLEDAD TO KING CITY

Abundant deep well data is available about 4 miles due south of Soledad on the Arroyo Seco Road in Well No. 15 (plate 1, Table 1). This well was abandoned at 2326' in basement rock. Sand and gravel extend to a depth of 1050 feet, below which sand, gravel, and clay with high resintivity streaks are present to 1450 . Thin interbedded sands and clays extend to the top of basement at 1780 feet. Numerous wells to the south and southeast of well No. 15, which extend across the Arroyo Seco cone to King City, have a thick, well-devleoped section of Paso Robles sands and gravels in excess of 500 feet in net thickness. They fill the valley, and outcrop in long bordering strips along both sides in the neighboring low hills. These outcrops continue south of King City to San Ardo.

Geologic Structure

The regional cross section (Plate 5) show that the Salinas Valley is an assymetric synclinal valley. It is bounded on the west by the Reliz-Rinconada Fault, which has elevated the Sierra de Salinas several thousand feet above the granite surface underlying the valley. The axis of the syncline appears to underlie the west-central position of the valley, with the basement surface rising gently to the east toward the Gabilan Range. There is some suggestion from water wells of a normal fault being present at least in localized areas, along the edge of the Gabilans.

The Salinas Valley trough has received sediments from Miocene time to the present along the westerly part of hte basin, the older sediments being overlapped towards the east. Two oil test wells drilled withint he last 4 years (Plate 1, Table 1, wells 14 and 15) found Pliocene beds resting on basement rocks at about 2000 feet. Depth to basement beneath the westerly alluvial fans is estimated to be 6000 feet, or deeper.

The Pliocene outcrops along the westerly edge adjacent to the Reliz-Rinconada Fault, between Spreckels and the Arroyo Seco, dip about 20° to the east, placing the axis of the basin syncline in the vicinity of the present course of the Salinas River. The Division of Mines Gravity Map (Figure 5) confirms this interpretation.

Cross section B-B' (Plate 5) is based on an interpretation of 2 short seismic lines run along the edge of the valley south to Spreckels. This interpretation shows the basement being down-faulted on the north side an estimated 2500 feet. The Pliocene and Pleistocene sediments being younger than the age of the faulting, are shown dipping northwards into the valley, unfaulted.

The Structural Contour Map on the base of the Pliocene (Plate 2) shows that the basinal synclinal axis continues toward Monterey Bay along the Salinas River. No faulting in either the Aromas strata or the Deep Zone in the coastal area could be proven from the many electric logs. This writer has concluded from his interpretation of the available data that if faulting does occur in the area along the coast between Marina and the Springfield District, it is most probably pre-Pliocene in age.

Fairly good correlations in the Springfield District suggest a north-south synclinal axis between the bay and the Elkhorn Slough. This syncline is shown on Plates 2 and 8.

Faulting

Two unmapped faults are shown on Plate 1 which are postulated from subsurface data.

1) Elkhorn Slough Fault. Evidence for this fault, though not compelling, is strongly suggested from subsurface contouring along both sides of the slough. The east side is the upthrown side, and there may be some lateral movement, as well.

2) Alisal Fault. Evidence for this fault is strongly suggested from a number of deep water wells.

Water well No. 29 (Table 2, Plate 1) hit granite at 700 feet, while wells to the east and west are 1000 feet deep. Farther to the southeast, wells 25 and 26 (Table 2) both hit granite, or granite rubble, at elevations which indicate an offset. This is shown on Plate 9, Cross-Section E-E'. This fault is thought to trend to the southeast to Chualar Canyon along the east side of a line of low hills which rise seventy feet above the surrounding valley floor. The westerly side is upthrown. These hills are shown on the Gonzales 1" = 1 mi. sheet of Dibblee's open file Geologic Map as being older fan gravel, Qog.

3) Reliz-Rinconada Fault

The northerly extension of this fault is shown to traverse westerly from the hills along River Road south of Spreckels (Cross Section B-B', Plage 5), cutting in the subsurface across Fort Ord along the south side of a subsurface gravity anomaly encountered by Seick (Reference 32). From this point, the fault is projected into Monterey Bay (see Cross-Section I-I', Plate 6) where the subsurface correlations suggest an anticline with the north side downdropped. There is no surface evidence of faulting. The faulting is probably Pre-Pleistocene in age.

THEN DOES NOT CUT QTP

MCFC AND WCD WELL NO. 1 (14S/2E/6L1)

Location

North Bank of Salinas River 1/2 mile east of Monterey Bay shoreline and Mulligan Hill topographic marker.

Section 6	T14S/R2E Surface elev 10 feet
Well Drilled For:	Monterey County Flood Control and Water Conservation District
Drilled by:	Salinas Valley Pump and Drilling, Salinas, CA, succeeded by Salinas Pump Company. Spudded September 27, 1976
Test Hole:	Bit size 12 1/4" to 1562' 7 7/8" to 1809

Drilling History

9/24	Drilled and set 30" conductor pipe in 36" hole. Landed in solid clay. Grout cemented. Drilled 12 5/8" hole to 1560 Drilled 7 7/8" hole to 1809
9/30	Lost drill collar in hole, top at 1550. Fishing. Failed to recover fish.
10/2	Ran Welenco E log to 1775
10/4	Ran Go International E log suite to 1560. 1. Induction Log 2. Compensated Density Log 3. Micro Log 4. 60 sidewall samples
10/7	Opening Hole from 12 5/8" to 17 1/2"
10/10	Reamed to 1560
10/10-18	Reamed hole to 28 1/2"
10/19	Lost slips in hole. Fishing. Pushed slips to bottom.
10/20	Reaming 26 1/2" hole to 1560.
10/22	Finished reaming at 1560.
10/24	Installing casing. Ran to 1560. Ran 2" gravel feed line to bottom.
10/28	Begin gravel packing. Two inch feed line parted at 60' after packing 10 joints. 48 pots in hole from 1299'. Install 3" gravel feed line to 840 feet.
10/30	155 pots in hole. Total 10 tons
11/2	Swabbed and installed total of 165 tons of gravel. Top at 802'.
11/2	Swabbed and washed bottom 200' of hole. No sand recovered. Well clean. Ran temperature survey.
11/4	Finished cementing with 1750 sacks.

11/8	Commence swabbing.
11/9	Swabbing. Fluid level at 25 feet in AM
11/10	Well flowing 120 gpm 506 ppm CL 1800 TDS
11/11	Rig moved off location
	Formation water tested 186 ppm CL and 780 ppm TDS
11/14	Water Analysis 122 ppm CL and 550 ppm TDS
11/19	Installed Pump
11/22	Commence well devleopment
12/2	Develop well. 68 hours gross time
12/6	Commence 48 hours pump test
	9 A.M. Artesian Flow 100 gpm. Water temperature 93'.
	Performed Rosson Sand Test,

Casing Record

102'	30" I.D. Cu-Bearing Steel Conductor Casing
600'	16" I.D. x 3/8" wall, Cu-Bearing Steel Casing
4'	16" - 12" Cu-Bearing Reducer
280'	12 3/4" O.D. x 1/4" Wall Cu-Bearing Casing
680'	12 3/4" O.D. x 1/4" Wall Full Flo Shutter Screen apertures 0.060", 120 openings per foot.
20'	12 34" O.D. x 1/4" wall blank Cu-bearing casing with 1/2" welded steel plate on bottom

3 centralizers welded to casing every 60 feet from bottom to surface

Gravel Specifications

97-100% passing #3
90-98% passing #4
60-85% passing #6
10-25% passing #8
0-1% passing #16
Monterey Sand Co., Monterey, supplier

Cementing Data

1560 sacks of treated cement, 0-802', supplied and cemented by Majors Cementing Co., Inc., oil well cementers, Bakersfield.

Results of 48 Hour Pump Test (December 6-7, 1976)

Rate	Pumping Level
1500 gpm	137'
1800 gpm	150'
2100 gpm	164'
2600 gpm	196'

Specific capacity 12.5 gpm per foot of drawndown. At 196 feet, recovery to 18 feet in 30 minutes.

Final Water Temperature 90' F

Pump Test No. 2 July 7, 1979

Conducted by: Monterey County Testing Service, Salinas, CA.

Test Results

Static Water Level	=	4.0'
Pumping Water Level	=	136.0'
Drawdown	=	132.0'
Capacity gpm	=	2152.0
Yield of Well gpm/ft. D.D.		16.0

This test, performed 2.5 years after Test No. 1, showed an increase in specific capacity from 12.5 to 16.0 gpm/foot DD.

Final Rosen Sand Test 6.3 ppm

Water Quality

14/2/6L1	EC	CL	NO3
1976	830	146	1/40.02
1977	-	-	-
1978	860	146	-
1979	820	140	2.0
1980	835	146	1.6
1981	840	150	1.7
1982	850	152	-
1983	875	-	-

See Appendix for complete 1976 Quality Analysis

SUMMARY OF SIDEWALL CORE ANALYSIS

	No. of Cores	Average Porosity	Average Permeability (millidarcies)
Upper Member	5	33%	440
Middle Member	19	34%	570
Lower Member	12	35%	1620

ummary of Porosities from Compensated Density Log

Upper Member	34%
Middle Member	34-36%
Lower Member	36%-42%, ave 37%

Summary of Grain Size Measurements

Upper Member	Mostly silty	Exception, 886-896 = .010
Middle Member	.005 - .010	
Lower Member	.010 - .020	

Sample Description

Depth in Feet	No. of Feet	Lithology
0-6	6	Top Soil
6-15	9	Blue Sandy Clay
15-32	17	Fine Blue Sand
32-60	28	Blue Clay with Sea Shells
60-75	15	Blue soft sand
75-102	25	Blue Clay
102-132	30	70% sand, 30% blue clay, shell frags
132-190	58	60% med-grained sand Coarse grained sand, pea gravel. Felspar chert qtz, shale interbedded with blue clay
190-203	13	Blue Clay
203-220	17	Gravel A. A. with shell frags
220-240	20	Gravel
240-280	40	Pea Gravel, Sand and Clay (10%)
280-305	25	Dk Grey clay;
305-320	15	Gravel streaks interbedded with blue clay
320-335	15	Gravel
335-343	8	Tan Silty Clay
343-360	17	Gravel
360-412	52	Yellow and blue clay with think streaks of gravel
412-480	68	Gravel, few thin clay streaks
450-520	40	Blue and yellow clay, minor gravel
520-570	50	Gravel with Streaks of Clay, shell frags
570-595	25	Sand, Clay, coarse qtz and chert sand, some granitic frags sand and clay
595-600	10	Yellow clay
600-618	18	Fine red silty sandstone
618-720	102	A. A. w/red siltstone, minor gravel

NOTE:

200-280	180' Aquifer
290-360	Lower 180 Foot Aquifer
410-480	Upper 400' Aquifer
520-570	Lower 400' Aquifer
676-724	Salty sand
724	Base of Aromas Red Sands ←

724-784	60	Gravel and clay streaks
784-794	10	Coarse gravel
794-886	92	Clay and gravel streaks
886-896	10	Sand, loose
896-996	100	Silty, clayey sand
996-1020	24	Clay
1020-1072	52	Sand
1072-1086	14	Clay
1086-1094	8	Sand
1094-1102	8	Clay
1102-18	16	Sand
1118-1150	32	Clay, yellow, and dark gray, silty
1150-1192	42	Sand and pea gravel
1192-1205	13	Clay, shell frags
1205-1285	80	Sand
1285-1296	11	Clay
1296-1320	24	Sand Streaks
1320-1332	12	Clay
1332-1348	16	Sand
1348-1355	7	Clay
1355-1410	55	Sand
1410-1438	28	Clay, shell frags
1438-1495	57	Sand, shell frags
1495-1505	10	Clay
1505-1560	55	Sand
1560-1630	70	Sand, pebbly, abund. white qtz. grains, minor cemented biotitic sand, few crs granitic frags
1630-1645	15	Clay, claystone, silt 50% 50% fine-crse sand and silt
1645-1660	15	Siltstone, gray brown to medium gray, sandy 40% fine to medium grained sand and lt gy silt, 60%, few cemented ss chips
1660-1675	15	Increase in fine cemented gray ss chips, biotitic
1675-1690	15	Clay, soft, plastic, dark gray 70%, yellow-brown claystone 30%
1690-1705	15	Sandy silt, mushy, 95%
1705-1720	15	Sandstone med. grey, fine-med., well sorted, silty, friable
1720-35	15	Sandstone a.a. and 50% loose fine to coarse grey sand, botitic, rounded to subangular
1735-50	15	Sand, light gray, very fine to coarse, poorly sorted, silty biotitic
1750-1765	15	Cemented fine ss, silty claytstone and sandy siltstone,

1765-1809	44	medium grey Siltstone and claystone, brown gray, fish scales, silt and clay

DEEP ZONE SANDY COUNT

	Interval	Net Sand	Remarks
Upper	740-880	45	10 think streaks
	886-896	10	Good
	910-1000	90	Fine, silty
Middle	1020-1072	52	Fair
	1085-1094	9	Fair
	1102-1118	16	Fair
	1150-1190	40	Fair
	1206-1244	38	Fine & silty
	1252-1284	32	Fair
	1298-1318	16	Silty
	1332-1343	11	Silty
Lower	1376-1408	32	Good
	1440-1490	50	Good
	1510-1560	50	Good, Clean
		491 Total Sand	

Note: Final Sand County used in Isopach Map (Plate 3) is 370 feet.

WATER QUALITY FO WELLS
PERFORATED SOLELY IN THE DEEP ZONE

Seven wells along the coastal area have been perforated exclusively in the Deep Zone. These are wells A through G, shown on Table 7 and on Plate 4. They cover an area of 13.5 square miles (9 x 1.5) between Moss Landing and Marina.

Castroville Irrigation Report Well E (14S/2E/6L1)

The Flood Control Well, is the first well to produce groundwater from the lowermost portion of the Deep Zone. The top performations at 880 feet are nearly 300 feet below the base of the 400 foot aquifer, and the lowermost perforations at 1560 feet are near the base of the fresh water bearing strata.

The water from this well is Class 1 water. Water quality since 1976 has essentially remained constant. It has been used to irrigate 570 acres of artichokes for the past five years, beginning in 1979 (see Table 7).

Well C (14/2/19Q3)

Well C, P. G. & E. well, was completed in the interval 1220-1550 at an initial pumping rate of 1950 at 300 feet. The well was artesian at its inception. It soon became apparent that the quality of the water in this well was different than the County well (6L1) and not as satisfactory. Chloride, adjusted SAR and TDS were found to be higher. It was also discovered that the chloride was higher at 500 gpm (342 ppm) than at 2000 gpm (218 ppm). This appears to indicate that a higher withdrawal rate may bring fresher water into the well.

Well D (13S/1E/36J)

Well D, Monterey Dunes South Well, is a recompleted domestic well locate din the coastal sand dunes. Originally drilled to 687 feet in 1972 with perforations form 396 to 648, the well developed salt water intrusion. For economic and political reasons, the decision was made to re-enter the well, drill through the Deep Zone, cement off the shallow interval and perforate the Deep Zone. This was done in 1976.

Quality in the deepened well rose gradually from 156 ppm Cl & 850 ppm TDS in 1977 to 270 ppm CE by the end of 1980. Since then, it has leveled off at 290 ppm CE

MCFC WATER QUALITY STUDY OF WELLS 19Q3 AND 6L1

The high sodium level in wells 19Q3 and 6L1, as shown in Table 7, prompted Flood Control, in 1982, to authorize a study of the potential long-term effects of soidium on the Castroville soils (Reference 2). The adjusted SAR of 20.3 in 19Q3 and 12.4 in 6L1 exceed the U. S. D. A. "Severe Problem" value of 12% (Tables 1 and 2 of Reference 2).

Soils were analyzed and found to have slow internal drainage. The natural water table is 3 to 5 feet from the surface. The conclusion of the report was that no apparent damage had as yet been observed in the soils; nevertheless, the abnormally high adjusted SAR suggests a long-term potential hazard.

Recommendations of the Report:

1) Establish a 10-year bi-annual monitoring program for sampling and analysis for both water and soils;

2) Encourage tile drainage system installations; and

3) No soil and/or water amendments are recommended for the County well (6L1), whereas, the additional gypsum has been recommended for 19Q3. Since gypsum was already being applied to this land, the recommendation required no additional expense to the owner.

The quality differences in these two wells may be reflected in the individual completion procedure of each well. Well 6L1 was perforated from 880 to 1560, and well 19Q3 was from 1220-1550. This leads to the speculation that the water above 1220 (880-1220) has less Na and less Cl than the lower waters. The recommendation herein is, in future wells, to begin perforations at a higher level than at 1240 in order to achieve a more balanced water quality.

TABLE 7

Table 2. Water Analysis of Well NO. T14S/R2E-6L1
County Deep Well - 900' Aquifer With Initial Tests in 1976.
Used for Irrigation of 570 Acres of Artichokes 1979, 1980, and 1981 Cropping Seasons

	Year	ECw mmhos/cm	Na meq/L	Ca meq/L	Mg meq/L	HCO_3 meq/L	adj. SAR	pH	Cl meq/L
2/	1976	0.825	6.6	0.55	0.30	3.48	12.5	8.4	4.2
1/	1979	0.820	6.7	0.60	0.26	3.36	12.4	8.1	4.0
1/	1980	0.835	---	---	---	---	---	---	---
1/	1981	0.840	7.1	0.84	0.30	3/ 3.11	12.3	8.4	4.2
	Average	0.830	6.8	0.67	0.29	3.32	12.4	8.3	4.1
5/	1982	0.850	6.22	0.85	0.25	3.20	10.93	8.3	4.29
5/	1983	0.875	6.30	0.76	0.25	3.20	11.53	8.3	4.23

WELL NO. T13S/R2E-19Q3 Deep Well - 900' Aquifer With
Initial Tests in 1980 and Used For Irrigation in 1980 and 1981 Cropping Seasons

	Year	ECw mmhos/cm	Na meq/L	Ca meq/L	Mg meq/L	HCO_3 meq/L	adj. SAR	pH	Cl meq/L
4/	1980	1.100	---	0.50	0.41	4.02	---	8.2	5.4
1/	1981	1.150	9.7	0.49	0.26	3/ 3.88	20.7	8.2	6.0
5/	1982	1.150	8.96	0.47	0.33	3.09	18.49	8.2	6.43
5/	1983	1.380	11.40	1.36	0.49	4.00	20.20	8.2	8.46

1/ Data from Monterey County Flood Control and Water Conservation District Laboratory

2/ Tests of 12/22/76 - Soil Control Laboratory, Watsonville

3/ Estimated Value from alkalinity ($CaCo_3$) by Gerald E. Snow, Ph. D.

4/ Tests of 4/18/80 - Private Laboratory

5/ Values provided by Gerald E. Snow, Ph. D., MCFC & WCF, August 1983

<u>NOTE</u> This Table is adapted from Reference 2

OTHER COASTAL WELLS

Wells A, B, and F are perforated in the upper member and contain Class 1 groundwater.

Well A (13S/2E/24G), in the Prunedale Hills, has excellent quality. This well pumped 450 gmp from 80 feet of zone (about 50% sand) with a TDS of 205 ppm, Cl 42 and Na 32 ppm.

Well B (13S/2E/17G) P. G. & E. Plant at Moss Landing was abandoned because of collapsed casing. The chloride was 147 ppm, and the TDS 602 ppm.

Well F (14S/2E/18D) near Neponset. Perforated 666-834. The well was originally drilled for use in Highway 1 construction, to be used subsequently for irrigation. During the well development, there was difficulty in pumping the well clean. After several days of pumping mud and sand, the well was plugged back. Smaller perforated casing was installed. When pumped, the volume was insufficient for irrigation, so the well was shut in. There is every indication from this geological study to believe that a well at this location could be developed satisfactorily from a perforated interval similar to well 6L1 (the Flood Control Well).

Marina - Fort Ord East Garrison

Well G (14S/2E/32E) City of Marina Well No. 10

Well G is the fourth well along the coast which is perforated in the lower portion of the Deep Zone, and its quality is the best to date. The well was drilled by the City of Marina to replace wells performated in the shallow zones (180 and 400 foot aquifers) which, over the past several years have become progressivley intruded by salt water. The Deep Zone ws regarded as the sole remaining potential source of fresh groundwater for the City.

The well was drilled and completed in 1983. Testing in July and August revealed excellent quality from 160 feet of perforations between 910 and 1520 feet. The conductivity measured 540 and the chlorides 53.0 ppm.

Spreckels

Well H (15S/3E/28A), located along the River Road near Spreckels, is a California Water Service Company well perforated in the upper member of the Paso Robles, with high volume and good quality.

Spence

Well I (15S/4E/20J) is a nursery well on Potter Lane, south of Spence, perforated 685-70, producing very good groundwater. The shallow sands in this area are of poorer quality. The perforated interval is logged as "white sand" and is regarded as Paso Robles formation underlying terrace and alluvial fan material. These deeper sands appear to underlie the easterly portion of the fan areas all the way to Soledad.

City of Soledad

Well J (T17S/R6E/28B) is a city of Soledad well, well perforations 640-690. This well produces water of excellent quality. Shallow water in this area is over 1000 ppm TDS. Deeper sands, below the shallow alluvial deposits, appear to be present east of a line between Soledad and Greenfield and are but sparingly used. East of the town of Greenfield, all of the alluvial water is Class II and Class III. It appears that better water in the Paso Robles formation may be present.

King City Area

East Side

Wells K (19/8/18R) and L (19/8/33D1) are located on the mesa 1.5 miles northeast of King City. In this area, the alluvial water to 300 feet is poor (1500-4000 ppm TDS). Perforations in these two wells are below the alluvium, part bieng in the Paso Robles formation and part in a fossiliferous Pliocene sand. Water quality is about 900 ppm TDS, considerably better than the overlying alluvial water. Well L was drilled in 1952. Well K, about 1 mile NE of L1 was drilled as a confirmation well to tests the quality of the lower strata.

West Side

Well M (19/7/20A1) is perforated in the Paso Robles formation below a 200 foot clay pod, herein called the "Cowles Clay". This clay pod extends for about 4 miles NW-SE and 1 mile E-W. It grades into sand, gravel, and clay along the Salinas River.

The Paso Robles is well developed beneath the clay and contains several hundred feet of interbedded sands, gravels, and clays. Water quality of 20A1 is about 800 ppm TDS. This quality has held since samples were first analyzed in 1959.

Alluvial water, for the most part, is good in the King City area, so the need for better water is not as pressing as in some other areas. However, for areas where shallow alluvial water is unsatisfactory, the deeper Paso Robles formation may offer a viable alternative.

West Greenfield - Arroyo Seco Cone

Shallow alluvial water in the Arroyo Seco Cone is abundant and of excellent quality for irrigation. Consequently, most of the wells are drilled to the base of the alluvium, which is at about 300 feet. A few deeper wells perforate both the alluvium and the underlying Paso Robles formation and are consequently not included in Table 6.

The electric log of abandoned oil test well No. 17 (18S/6E/27) Plate 1, Table 1) in the Arroyo Seco Cone shows gravels and boulders extending down to 900 feet, 600 feet below the base of the alluvium. Below this depth are interbedded sands, gravels and clays. The base of the formation, for the purposes of this report is at about 1800 feet, below which point clay becomes predominant, althoug the water still appears to be fresh. Indeed, oil test Well No. 15 (Plate 1, Table 1) was stated by the Operator to have fresh water to the top of basement at 1820 feet (-1560 feet).

Well N (Plate 4, Table 6) is a domestic well located at the eastern edge of the elevated fans (18S/6E/18H. The driller's log indicates that the top of the Paso Robles formation may be at 410 feet. No Salinas River alluvial material is present. The perforations are form 360 to 620 feet. Water quality is excellent.

Well P (Plate 4, Table 6) is a municipal well located in the northwest part of Greenfield (18S/6E/3LE) in the Arroyo Seco Cone. The well is perforated from 313 to 863 and produces water of excellent quality. EC is 540, TDS 341 ppm, CL 21 ppm, Na 32 ppm and NO_3 5.3 ppm.

Summary

A careful check of water well logs in Flood Control files shows 14 wells with perforations solely in the Deep Aquifer. Half of these wells are west of Highway 68 and half scattered between Spreckels and King City. All fifteen show uniformly acceptable water quality for their particular use. Three of the wells are for municipal use, six for irrigation, two for industrial, and three for domestic purposes. About thirty wells are perforated both in the alluvial and Paso Robles.

TABLE 8

DEEP ZONE WATER QUALITY FO WELLS
PERFORATED SOLELY IN DEEP ZONE

Plate 4 Well #	Year Drld.	Anal. Date	T/R/S	Perf. Int.	Ec	Cl	Na	NO_3	USE
A	1956	1983	13/2/24G	758-838	290	42	32	--	D
B	1951	1973	13/2/17	696-912	860	147	--	--	In*
C	1980	1983	13/2/19Q	1220-1550	1150	214	224	--	I
D	1977	1983	13/1/36J	1298-1448	910	182	170	--	D
E	1976	1983	14/2/6L1	880-1560	840	150	164	--	I
F	1974	1974	14/2/18D	666-864	557	38.0	--	--	I
G	1983	1983	14/2/32E	910-950 970-990 1020-1060 1170-1190 1480-1520	540	53.0	--	--	M
H	1980	1983	15/3/28A	680-730	660	62	42	--	M
I	1980	1983	15/4/20J	685-720	595	64	59	--	In
J	1978	1983	17/6/28B	640-690	565	26.0	41.5	0.3	M
K	1978	1983	19/8/18R	325-680	1178	116	44	0.0	I
L	1952	1976	19/8/33D1	703-08 725-94 809-27	1417	136	55%	0.0	I
M	1959	1983	19/7/20A1	456-976	1140	99	107.5	--	I
N	1979	1983	18/6/18H	360-620	585	2.5	12.5	--	D
P	1978	1978	18/6/36E	313-863	540	21.0	32.0	5.3	M

*Abandoned - collapsed caisng

D	Domestic
I	Irrigation
M	Municipal
In	Industrial

GROUNDWATER IN STORAGE, AND USABLE GROUNDWATER IN STORAGE

Methodology for Calculations

In calculating the groundwater reserves for the Deep Zone, the study area was broken up into six areas (Plate 4):

Area 1 Castroville Irrigation Project
Area 2 Prunedale Hills
Area 3 Springfield-Moro Cojo District
Area 4 Marina-Fort Ord East Garrison
Area 5 Central Valley and West Side
Area 6 East Side

These areas were planimetered to obtain surface area in acres. The total net thickness of sands and gravels was derived by a bed thickness count of the sand and gravel beds on the electric logs. The alluvium, alluvial fan material, and Aromas formations were excluded from the calculations, as well as clay beds within the deep zone. An average porosity value was assigned to each area for the purpose of calculating the net volume of pore space. These figures are believed to be a realistic balance between the porous gravels and coarse sands and the less porous materials, such as silty sands, packed sands, cemented sands and gravels.

Area 1 Castroville Irrigation Project

This area is a political area with a prescribed boundary. It is hydrologically, and geologically, connected with Area 5, on the south, and Area 3, on the north. The ground water in storage is 1,349,955 Ac. Ft. This amount appears to be reasonably well substantiated by drilling data.

Usable Groundwater

Usable groundwater for this area is difficult to determine due to the proximity of Monterey Bay and the possibility of salt water intrusion being commenced by over-pumpage. In order to determine the safe yield in terms of acre feet of annual pumpage, it is necessary to know (1) the amount of recharge for the area, (2) the approximate distance the fresh water-salt water interface is from the wells, and (3) the present volume of pumpage. It is felt that a review of the available pump tests of the four deep wells, together with additional pump testing of the wells and the drilling, testing, and monitoring of, as yet unspecified and unlocated test well(s), may furnish valuable information on the possibility of salt water intrusion into the deep zone. Until further testing and analyzing are done, the problem of affixing an amount for safe yield in the coastal area is deferred.

Area 2 Prunedale Hills

The amount of groundwater in place in the Paso Robles Formation is calculated at 298,000 acre feet. Most of these reserves are along the southerly and westerly borders. The Paso Robles sands tend to be thinbedded. They occur no deeper than a thousand feet. (See Plate 7, Cross-Section J-J). The usable groundwater is 29,800 acre feet, using a figure of 10% for specific yield.

Area 3 Springfield-Moro Cojo District

This area lies between the Bay and Elkhorn Slough, and from the Pajaro River south to Moss Landing. It is about 10 miles long and 2.5 miles wide and appears to contain good possibilities for production from the Deep Zone, as shown on Plate 6. The area is thought to be enterly underlain by the Deep Zone. Three deep abandoned oil test wells (wells 1, 5, 7 Plate 1, Table 1) logged sands and gravel down to a depth of over 1500 feet. The quality and well capacities are, of course, untested. The groundwater in place is calculated at 1,652,805 acre feet.

Usable Groundwater

Since no water quality data from the Deep Zone is available from any well in the area, the amount of usable groundwater is unknown. At some point in time a well must be drilled to the base of the zone and tested for quality and quantity. It is obvious that the quantity of usable groundwater can be substantial; however, the quality must be determined.

The geologic structure in Area 3 is shown to be synclinal in a north-south direction (see Plate 2 and Plate 8). However, additional data may modify this interpretation. If the structure is synclinal, a shown, the chance of finding fresh water would appear to be good, as the adjoining anticlincal fold to the west may act as a possible deterrent to salt water intrusion.

A test to the base of the Deep Zone herein recommended to be drilled and tested at a location in the vicinity of Oil Test Well No. 1 (Plate 1, Table 1) in T12S/R2E/Section 29. The location of this abandoned oil test well is 9000 feet from the Bay and 5000 feet from Elkhorn Slough.

Area 4 Fort Ord - East Garrison

The recently completed City of Marina well No. 10 (14S/2E/32E) adjoins Fort Ord near the southeasterly corner of the city. This well was completed in the Deep Zone (160 feet of perforations, top 910, base 1520). On a 24-hour pump test on August 6, the well produced 1550 gpm with a drawdown of

120 feet. Water quality is 378 ppm TDS and 53 ppm chloride, the best quality in the Deep Zone to date.

On the basis of this well, it is fair to speculate that the Deep Zone is a viable potential source of Class 1 groundwater along the northerly and northwesterly edges of Fort Ord. The southerly and westerly limits of viable production is unknown.

Groundwater in storage for Area 4 is calculated at 1,452,800 acre feet.

Usable Groundwater

The amount of usable groundwater in Area 4 is not known at the present time, although one would suspect that the excellent quality of the water, the sizable thickness of the sands and gravels, and the fact that the location of the well is 10,000 feet from the shoreline, would allow an optimistic estimate for this amount.

The pumping test of the Marina City Well No. 10 shows that the Deep Zone is under pressure, as the standing water level was found to be at 154 feet, with the perforations spaced between 920 and 1520 feet. The drilling and testing of a Deep Zone test hole near the Bay, and long-term monitoring of the present well, appear to be required in order to assign reasonable figures for usable groundwater and safe yield.

The amount of recharge into this area is believed to come from two sources: (1) percolation of rainfall through surface outcrops in the southerly portion of Fort Ord, and (2) subsurface mitigation within the Deep Zone from the southeast along the west side of the Salinas Valley groundwater basin. The excellent quality of the groundwater in the Marina well suggests that recharge from one or both of these sources is responsible for the good quality.

Area 5 Central Salinas Valley and West Side

This area, without question, contains the greatest amount of groundwater in storage, partly because the area is the largest, partly because the total sand and gravel count is thicker, and partly because the geologic structure appears favorable for the occurrence of a continuous thick section of Paso Robles between King City and Monterey Bay.

Although there is no deep well data between the Marihart Oil test well (15S/4E/31, Number 13 of Plate 1, Table 1) and wells 15 and 16 in T18S/R6E, a distance of 20.5 miles, the regional surface and subsurface geology, in conjunctionw ith the position and configuration of the valley syncline paralleling the Sierra de Salinas (Figure) compels this writer to extend the Paso Robles along this synclinal axis between the Bay and King City. Oil test wells 13, 18, 19, 21, and 29 each contain some 500 feet of net sand and gravel along the trend of the synclinal axis.

Calculated groundwater storag eis 16,448,250 acre feet.

Usable Groundwater

The amount of estimated usable groundwater is 3,618,615 acre feet. This is based on a specific yield factor of 22%, which is felt to be a viable balance betwene the boulder and sand content.

The above estimate is open to argument because of the unknowns inherent in the area, namely (1) pausity of test data in the southerly portion, (2) lack of drilling and testing data between wells 13 and 15 (Plate 1, Table 1), as a distance of 20.5 miles.

Offsetting this lack of information are several positive conclusions on the regional geologic structure and sand thickness (Plates 2 and 3) and the water quality data from wells in the Deep Zone (Plate 4, Table 6).

Area 6 East Side

The East Side contains alluvial fan deposits down to 800 feet. Most of these deposits are red and/or brown, think beeded, alternating deposits of clays, sand, sandy clay, gravel, and gravelly clay. About 75 irrigation wells are operating in this long strip.

Wells drilled within 1.5 miles of the mountainfront generally drill to basement. Farther west, however, the basement surface is lower, and it is this strip that appears to have some undrilled Deep Zone possibilities in Paso Robles sediments which underlie the fan deposits. Depth to the top of these sediments vary from 700 to 900 feet. The thickness of these Paso Roblesis estimated to be as much as three feet to four hundred feet. It seems reasonable to assume that the percentage of coarse materials will increase towards the west.

An amount of 332,800 acre feet of groundwater in storage and 49,920 acre feet of usable groundwater are calculated for this long, narrow strip. It would seem that deeper drilling might prove up more reserves from the lower strata.

Usable Groundwater

TABLE

Estimated Amount of Groundwater in Storage
and Useable Groundwater in Storage in Deep Aquifer

Area	Surface Area (Acres)	Avg. Saturated Thickness In Feet	Porosity %	Groundwater In Storage (Acre Feet)	Spec. Yield %	Usable Groundwater (Acre Feet)
1	11,610	350	.33	1,340,955		
2	14,900	100	.20	298,000	.10	29,800
3	14,310	350	.33	1,652,805		
4	17,600	250	.33	1,452,800		
5	187,980	350	.25	16,448,250	.22	3,618,615
6	16,640	100	.20	332,800	.15	49,920
				21,525,610 Ac. Ft.		4,615,416 Ac.Ft.

DEEP ZONE RECHARGE

Summary

The principal sources of recharge into the Deep Zone, as shown on Plate 4A, are as follows:

1. The southwest flank of the basin between Monterey Bay and San Ardo.
2. The western flank of the Gabilan Range between Prunedale Hills and San Ardo.
3. Subsurface recharge into the Paso Robles from stream flow of the Salinas River between San Ardo and Spreckels.

Total recharge is estimated to be 65,500 acre feet per year, about one third of this amount being provided by each source, as shown in Table .

The three sources have been subdivided into a total of 13 sub-areas.

Table 4 represents a prelimianry estimate of the amount of recharge into the Deep Zone. Since no detailed studies have been made to date of this particular source of groundwater recharge, the above figures are considered preliminary.

Johnson, Table (Reference 22, Groundwater in North Monterey County) on page 42A states that "few quantitative data are available for the preQuaternary formations, which extend under the North County area; therefore, no estimates of underground flow were made for these deposits".

Durbin, et al (Reference 13, 1979, "Two Dimensional and Three Dimensional Digital Flow made for the Salinas Valley Groundwater Basin, California") outlines in detail the annual small stream recharge of 51,000 acre feet into the Salinas River and 45000 acre feet of recharge into alluvial fans and terraces along both edges of the valley between the Bay and San Ardo. In addition, six thousand acre feet are shown to enter the system as direct recharge from precipitation: 5000 acre feet in the Prunedale Hills through the Aromas sand and 1000 acre feet north of Marina through a large sand dune deposit.

Durbins only reference to recharge through subsurface inflow is 21000 acre feet from a large area of "older marine rocks" on the east side of the valley between King City and San Ardo. This area is the Gabilan Mesa, which is underlain by the Poncho Rico silts, claystones, and thin interbedded fine sands.

The mesa tilts toward the Salinas River from Peachtree Valley at 4° to the southwest in a broad monoclinal structure. It terminates along the easterly edge of the valley floor.

Durbin's water balance is as follows:

Recharge

Salinas River	156,000 acre feet
Small Streams	96,000
Pumpage Return	217,000
Salt Water Intrusion	11,000
Recharge from Precipitation	6,000
Subsurface Inflow	21,000

	507,000 acre feet

Discharge

Pumpage	482,000
Evapo-transpiration	25,000

	507,000 acre feet

The above water balance is concerned primarily with the shallow) and 400 foot aquifers.

Adjusting the above balance to include recharge into the Deep Zone will require the input of total recharge from all of the sources mentioned at the beginning of the chapter, with a like amount of outflow from the Paso Robles into the Monterey Bay.

Stream flow measurements taken by the Flood Control Office at Bradley, Soledad, and Chualar during the years 1968-69 through 1977-78 provide a possible clue on potential recharge from flow measurements of the Salinas River during this time period. Data for unmeasured stations has been extrapolated from rates of absorption between measured stations.

Stream Flow Percolation Recharge

Bradley - Soledad	121,240 acre feet
*Bradley - King City	76,300
*King City - Greenfield	20,200
*Greenfield - Soledad	24,710
Soledad - Chualar	154,060
Bradley - Chualar	275,300

*From interpolation of length of stream channel and average absorption per mile of channel.

Streambed absorption during this 10-year period compares favorably with averages occurring since construction of the dams. It is, therefore, considered reliable for long-term evaluation, in the inion of MCFC.

Plate 4A shows (1) the sources which contribute recharge into the Deep Zone, and (2) the direction of groundwater flow. Recharge from the flanks of the basin migrates down into the subsurface of the valley floor. Recharge from the Salinas River into the Paso Robles begins near San Ardo and continues along the curve of the river to as far north as Spreckels. This recharge is pictured as percolating downward into the Paso Robles and migrating northwards towards the Bay through an area which extends east-west from near the base of the Sierra de Salinas eastward to a somewhat sinuous line roughtly paralleling Highway 101, about one to two miles to the east. The location of this line has been drawn from deep well data. The westerly portion of Prunedale Hills and the Springfield-Moro Cojo Dsitrict are shown to receive part of this recharge. The portion of the Salinas River which is most likely to provide recharge to the Paso Robles sands and gravels lies between San Ardo and Soledad, where the sediments lay directly below the shallow alluvial gravels. Recharge from the Arroyo Seco Cone is probably because of the presence of coarse Paso Robles sediments directly beneath the shallow alluvial ravels.

TABLE 9

List of Sources of Recharge for each Groundwater Storage Area

Area			Source of Recharge (Plate 4A)	Recharge Sub-Area
1	C I P	a.	Subsurface inflow thru Qtp from southeast and east	R10-13, R-3, R-7
		b.		
2	Prunedale Hills	a.	eastern hills	R-6
		b.	subsurface inflow	R-10-13
		c.	probable inflow from Carneris River	R-6
3	Springfield-Moro Cojo	a.	subsurface inflow from east	R-6
		b.	subsurface inflow from southeast	R-10-13
		c.		R3
4	Marina-Fort Ord East Garrison	a.	direct rianfall recharge from south	R5
		b.	subsurface inflow from southeast	R10-13, R-3
5	Central Valley and West Side	a.	percolation and runoff from Sierra de Sainas	R-4
		b.	rainfall recharge on Qtp outcrop	R-1, 2, 8, 9
		c.	percolation from Salinas River	R10, 11, 12, 13
		d.	probable recharge from irrigation returns	R-3
6	East Side	a.	Runoff and subsurface percolation thru alluvial fans from Gabilan Range	R-7
		b.	subsurface inflow from southeast along westerly margin	R-10-13, R-3
		c.		

SALINAS RIVER ABSORPTION (RECHARGE)

		Length of Channel in Inches	Measured Absorption Ac Ft	Less ET	Net Available	Est Q/o Into Deep Zone	Estimated Recharge into Deep Zone Ac Ft.
R-10	San Ardo-King City		76330	8006	69330	10%	7000
R-11	King City-Coburn		20200	4000	16220	10%	1500
R-12	Coburn-Soledad		24710	4000	20710	-0-	-0-
R-13	Soledad-Spreckels		153760	8000	145760	5%	5000
R-3	Arroyo-Seco Cone			-	73730	10%	7500

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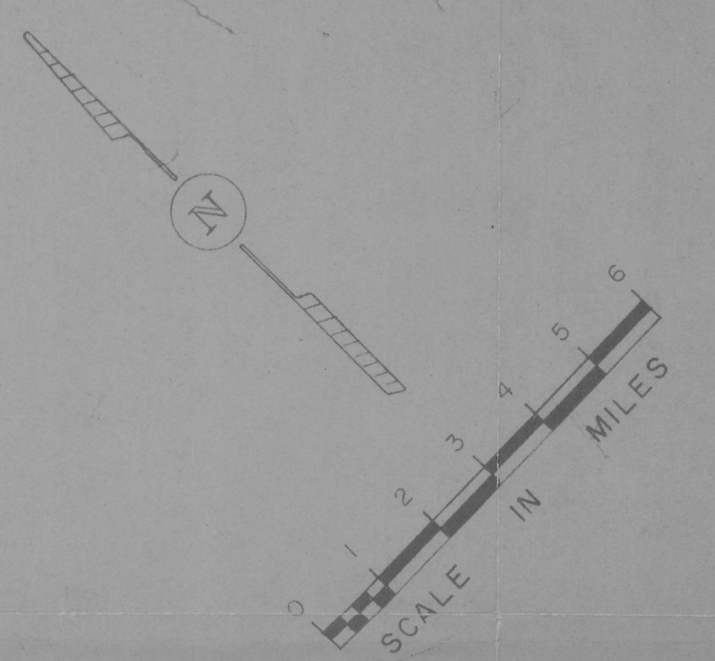

-LEGEND-

UNCONSOLIDATED DEPOSITS OF HOLOCENE THROUGH PLIOCENE AGE

Qal - ALLUVIAL DEPOSITS - RECENT

Qoa - OLDER RIVER TERRACES - PLEISTOCENE

Qaf - ALLUVIAL FAN DEPOSITS - RECENT TO PLIOCENE

Qd - WINDBLOWN SAND - RECENT AND PLEISTOCENE

Qls - LANDSLIDE

Qar - AROMAS RED SANDS OF PLEISTOCENE AGE

Qtp - PASO ROBLES SANDS, GRAVELS, CLAYS OR PLEISTOCENE AND PLIOCENE AGE

PARTLY CONSOLIDATED DEPOSITS OF PLIOCENE AGE

Tps - SAND

Tp - CLAYSTONE, SHALE, DIATOMITE

CONSOLIDATED ROCK OF TERTIARY AND PRE-TERTIARY AGE

Tm - MIOCENE MONTEREY SHALE

Tums - UPPER MIOCENE SAND

Tmms - MIDDLE MIOCENE SAND

BASEMENT ROCKS

Kgr - CRETACEOUS GRANITIC ROCKS

M - PRE-CRETACEOUS METAMORPHIC ROCKS

——— - CONTACT

— — — - APPROXIMATE CONTACT

—·—· - EASTERLY SUBSURFACE LIMIT OF PASO ROBLES STRATA

U/D - FAULT/···· CONCEALED/ — — — INFERRED/ A – ALISAL / B – ELKHORN

(7) - OIL TEST WELL

(3) - WATER WELL USED IN CROSS SECTIONS

TABLE - 1

CONTROL OIL WELL DATA

WELL No.	LOCATION	WELL DEPTH IN FEET	WELL No.	LOCATION	WELL DEPTH IN FEET
1	12S/2E-29	3,198	26	19S/7E-8	2,998
2	12S/2E-33	2,188	27	19S/7E-14	1,470
3	12S/2E-34	1,922	28	19S/7E-18	5,010
4	12S/2E-31	1,200	29	19S/7E-19	3,804
5	13S/2E-6	4,007	30	19S/7E-19	3,648
6	13S/2E-6	1,552	31	19S/7E-25	1,351
7	13S/2E-7	7,916	32	19S/7E-26	1,771
8	13S/2E-13	2,898	33	19S/7E-35	2,589
9	13S/2E-19	3,291	34	19S/8E-31	1,283
10	13S/2E-34	2,218	35	19S/8E-33	702
11	15S/1E-22	2,151	36	20S/8E-11	1,545
12	15S/1E-23	1,235	37	20S/8E-9	5,306
13	15S/4E-31	2,625	38	20S/8E-21	2,343
14	16S/5E-18	2,306	39	20S/8E-36	2,590
15	18S/6E-9	2,336	40	20S/7E-13	2,666
16	18S/6E-19	4,258	41	20S/7E	2,680
17	18S/6E-27	6,109	42	20S/7E	2,517
18	18S/6E-29	6,120	43	15S/3E-29	1,470
19	18S/6E-34	5,955	44	19s/7E-21	3,650
20	19S/6E-9	5,800			
21	19S/6E-11	4,120			
22	19S/6E-14	3,725			
23	19S/6E-23	3,809			
24	19S/6E-24	4,117			
25	19S/7E-5	1,511			

TABLE - 2

CONTROL WATER WELL DATA

WELL No.	LOCATION	WELL DEPTH IN FEET	WELL No.	LOCATION	WELL DEPTH IN FEET
1	13S/2E-17	1,283	26	15S/4E-6	1,094
2	13S/2E-15	1,014	27	14S/4E-30	608
3	13S/2E-23	676	28	14S/4E-29	300
4	13S/2E-24	686	29	14S/3E-26	700
5	13S/2E-24	636	30	15S/4E-20	786
6	13S/2E-19	1,610	31	15S/4E-9	584
*7	14S/2E-6L1	1,809	32	16S/5E-5	820
8	13S/1E-36	1,724	33	19S/8E-31	900
9	14S/2E-18	913	34	20S/8E-8	600
10	14S/2E-30	1,016	35	14S/2E-19	580
11	14S/2E-31	617	36	19S/8E-18	860
12	14S/2E-31	760	37	15S/2E-32E	1,520
13	15S/1E-1	862			
14	15S/1E-1	836			
15	15S/1E-1	856			
16	15S/1E-14	350			
17	15S/1E-14	750			
18	15S/1E-23	367			
19	15S/1E-24	605			
20	13S/2E-34	1,055			
21	13S/3E-5	530			
**22	14S/2E-22	1,715			
23	14S/3E-31	650			
24	15S/3E-4	1,020			
25	15S/4E-6	915			

SUSPECTED FAULTS

A - ALISAL FAULT 14S/3E

B - ELKHORN FAULT 13S/2E

* - COUNTY WELL NO. 1

** - COUNTY TEST HOLE NO.1

RICHARD R. THORUP
Consulting Geologist Monterey, California

PLATE - I
GEOLOGIC MAP
SHOWING CROSS SECTION LINES
AND SELECTED WELLS

Date: 12/82	Drawn By: B.T.V.
Scale: as shown	Revised 7/22/83
For: MCFC & WCD	


ELEVATION IN FEET
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000
-2200
-2400
-2600
-2800
-3000
-3200
-3400
-3600
13S/2E-6
CAPURRO NO.1
13S/2E-7
BAYSIDE DEV. CO. VIERRA NO.1
13S/2E-19
TEXACO, INC.
PIERI NO.1
13S/2E-19Q3
LEONARDINI
13S/1E-36J1
MONTEREY DUNES COLONY
14S/2E-6L1
MCFC & WCD NO.1
14S/2E-18
ARMSTRONG
NOT IN USE
14S/2E-19
14S/2E-30
MARINA
(TEST WELL)
14S/2E-31
14S/2E-32E
GROUND SURFACE
SEA LEVEL
SEA
LEVEL
CLAY
SAND WITH
FINE GRAVEL
Pp
FOSSILS
SAND - AGE ?
Tm
Tm
GRANITE
580'
617'
913'
1016'
1520'
1610'
1488'
1724
1809'
3291'
4007'
7916'
-LEGEND-
— WATER WELL
— ABANDONED OIL TEST WELL
— TOP OF PASO ROBLES - BASES OF AROMAS
— TOP OF UNUSED, OR VIRTUALLY UNUSED, GROUNDWATER
— "1000 FOOT" SAND
— TOP OF BASAL MEMBER
— BASE OF FRESH WATER SANDS AND GRAVELS
(BASE OF PASO ROBLES)
— WELL PERFORATIONS
CROSS SECTION- M - M'
0 2000 4000 6000
0 200 400 600
SCALE IN FEET
HORIZONTAL 1"=2000'
VERTICAL 1"=200'
NOTE
FOR ADDITIONAL LEGEND SEE PLATE-5
RICHARD R. THORUP
Consulting Geologist Monterey, California
PLATE-10
MOSS LANDING TO MARINA
Date: 12/82
Drawn By: B.T.V.
Scale: as shown
Revised: 7/22/83
For: MCFC & WCD


MONTEREY COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT
STATE OF CALIFORNIA
SALINAS VALLEY
GEOLOGIC INVESTIGATION
DRAWN BY D.F.H. & J.N.K.
CHECKED BY
SUBMITTED BY
APPROVED BY
District Engineer
DATE 6-3-68
SCALE
SHEET 1 OF 1
DRAWING NO.
CASTROVILLE
SALINAS
CHUALAR
GONZALES
SOLEDAD
GREENFIELD
PRESSURE AREA
EAST SIDE AREA
FOREBAY AREA
Johnson Canyon Rd
Gonzales Rd
Spence Rd
Williams Rd