STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

STATE WATER RESOURCES BOARD
BULLETIN NO. 18

SAN LUIS OBISPO COUNTY INVESTIGATION

Volume II
Appendixes

GOODWIN J. KNIGHT
Governor

HARVEY O. BANKS
Director of Water Resources

May, 1958

STATE OF CALIFORNIA

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APPENDIX A

AGREEMENT, AND ITS SUPPLEMENTS, BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTY OF SAN LUIS OBISPO, AND THE DEPARTMENT OF PUBLIC WORKS

AM 02076

TABLE OF CONTENTS

TABLE OF CONTENTS

APPENDIX A

AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTY OF SAN LUIS OBISPO, AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, entered into as of the 1st day of July, 1953, by and between the State Water Resources Board, hereinafter referred to as the "Board", the County of San Luis Obispo, hereinafter referred to as the "County", and the Department of Public Works, State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H:

WHEREAS, the Budget Act of 1952 (Chapter 3, Statutes of 1952) by Item 268.5(b) appropriated the sum of $20,000 for the initiation of a comprehensive survey of the water resources of San Luis Obispo County; and

WHEREAS, said survey has been initiated under a three-year program of investigation and the foregoing sum of $20,000 has been expended during the fiscal year 1952-53; and

WHEREAS, by the State Water Resources Act of 1945, as amended, the Board is authorized to make investigations, studies, surveys, hold hearings, prepare plans and estimates, and make recommendations to the Legislature in regard to water development projects, including flood control plans and projects; and

WHEREAS, by said act, the State Engineer is authorized to cooperate with any county, city, state agency, or public district on flood control and other water problems and when requested by any thereof may enter into a cooperative agreement to expend money on behalf of any thereof to accomplish the purposes of said act; and

WHEREAS, the County has requested the Board to enter into a cooperative agreement to conduct a comprehensive investigation of the water resources of San Luis Obispo County; and

WHEREAS, the Board has requested the State Engineer to cooperate in conducting a comprehensive investigation of the water resources of San Luis Obispo County and to formulate a report thereon;

NOW, THEREFORE, in consideration of the premises and of the several promises to be performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

ARTICLE I - WORK TO BE PERFORMED:

The work to be performed under this agreement shall consist of (1) a complete review of reports of prior investigations concerning the water resources of San Luis Obispo County, (2) field investigations and office studies to determine (a) the location, occurrence, and condition of water resources of the County, both surface and underground, (b) present water utilization including its nature, extent, and a survey of water service areas, (c) land classification survey to determine probable ultimate areas of irrigated land, (d) ultimate water requirements, (e) preliminary general plans and estimates of cost for development and utilization of local water resources of the County, (f) required supplemental water supply from outside sources, (g) possible outside sources for required supplemental supply, and (3) formulation of a report thereon.

The Board by this agreement authorizes and directs the State Engineer to cooperate by conducting said investigation and formulating said report and by otherwise advising and assisting in formulating solutions to the water problems in San Luis Obispo County.

During the progress of said investigation, all maps, plans, information, data, and records pertaining thereto which are in the possession of any party hereto, shall be made fully available to any other party hereto for the due and proper accomplishments of the objectives hereof.

The work to be done under this agreement shall be diligently prosecuted with the objective of completing the investigation and report by June 30, 1955, or as nearly thereafter as possible.

ARTICLE II - FUNDS:

On execution of this agreement, the County shall transmit the sum of Fifteen Thousand Dollars ($15,000) to the State Engineer for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury, for expenditure by the State Engineer in performance of the work proviced for in this agreement. Also upon execution of this agreement, the Board shall request the Director of Finance to approve the transfer of the sum of Fifteen Thousand Dollars ($15,000) from funds appropriated to the Board by Item 262 of the Budget Act of 1953, to the said Water Resources Revolving Fund for expenditure by the State Engineer in performance of work provided for in this agreement during the fiscal year 1953-54.

It is understood by and between the parties hereto that the sum of Thirty Thousand Dollars ($30,000) to be made available as hereinbefore provided, is adequate to perform the above specified work during the fiscal year 1953-54, and it is the understanding that the County will make a further sum of Thirteen Thousand Dollars ($13,000) available at the commencement of the fiscal year 1954-55 which will be subject to a matching contribution in an equal sum by the

Board for the completion of said investigation and report, contingent upon the availability of County and Board fund for such purposes.

Notwithstanding anything contained in this agreement contrary hereto or in conflict herewith, this agreement is made contingent upon the funds being deposited in or transferred to the Water Resources Revolving Fund as provided herein for expenditure by the State Engineer in performance of the work provided for in this agreement. In the event any of the funds are not transferred to the Water Resources Revolving Fund by the Director of Finance as provided for herein within 30 days after the Board request such transfer, this agreement shall terminate and the unexpended balance of any funds deposited by the County shall be returned, provided that neither the Board nor the State Engineer shall be obligated to the County for any portion of the funds already expended.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the funds made available hereunder.

Upon completion and final payment for the work provided for in this agreement, the State Engineer shall furnish to the Board and to the County a statement of all expenditures made under this agreement. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to the Board and one-half of the total amount of all said expenditures shall be deducted from the sum advanced by the County and any balance which may remain shall be returned to the Board and to the County in equal amounts.

Notwithstanding anything herein contained to the contrary, this agreement may be terminated and the provisions of this agreement may be altered, changed, or amended, by mutual consent of the parties hereto.

IN WITNESS WHEREOF, the parties hereunto have executed this agreement as of the date first herein written.

Approved as to Form
and Procedure

/s/ H. C. Grundell
District Attorney
County of San Luis Obispo

Approved as to Form
and Procedure

/s/ Henry Holsinger
Attorney for Division
of Water Resources

Approved as to Form
and Procedure

Attorney, Department
of Public Works

APPROVED:

Deputy Director of Finance

:D.H.: J.W.A. : : :
: Form : Budget : Value : Descript.:
: DEPARTMENT OF FINANCE :
: APPROVED :
: Aug. 4 1953 :
: :
:JAMES S. DEAN, Director :
: :
: By /s/ A. Earl Washburn :
: Deputy Director of Finance :

COUNTY OF SAN LUIS OBISPO

By /s/ John Ruskovich
Chairman, Board of Supervisors

/s/ A. E. Mallagh (Seal)
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ C. A. Griffith
Chairman

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

FRANK B. DURKEE
Director of Public Works

By /s/ Russell S. Munro (Seal)
Russell S. Munro
Deputy Director of Public Works

A. D. Edmonston
State Engineer

By /s/ T. R. Merryweather
Administrative Officer

SUPPLEMENTAL AGREEMENT
BETWEEN
THE STATE WATER RESOURCES BOARD,
THE COUNTY OF SAN LUIS OBISPO, AND THE
DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintruplicate, entered into as of the 1st day of July, 1954, by and between the State Water Resources Board, hereinafter referred to as the "Board", the County of San Luis Obispo, hereinafter referred to as the "County", and the Department of Public Works, State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H

WHEREAS, the Budget Act of 1952 (Chapter 3, Statutes of 1952) by Item 268.5(b) appropriated the sum of $20,000 for the initiation of a comprehensive survey of the water resources of San Luis Obispo County; and

WHEREAS, by agreement heretofore entered into as of July 1, 1953, by and between the Board, the County, and the State Engineer, it was provided that the work to be performed thereunder shall consist of (1) a complete review of reports of prior investigations concerning the water resources of San Luis Obispo County, (2) field investigations and office studies to determine (a) the location, occurrence, and condition of water resources of the County, both surface and underground, (b) present water utilization including its nature, extent, and a survey of water service areas, (c) land classification survey to determine probable ultimate areas of irrigated land, (d) ultimate water requirements, (e) preliminary general plans and estimates of cost for development and utilization of local water resources of the County, (f) required supplemental water supply from outside sources, (g) possible outside sources for required supplemental supply, and (3) formulation of a report thereon; and

WHEREAS, under said agreement the County made available the sum of Fifteen Thousand Dollars ($15,000) which was matched in an equal amount by the Board for expenditure by the State Engineer in the performance of the work provided for in said agreement; and

WHEREAS, it was the expressed intention in said agreement that at the commencement of the fiscal year 1954-55 the County would make available a further sum of Thirteen Thousand Dollars ($13,000) subject to a matching or contribution in an equal sum by the Board for the completion of said investigation and report; and

WHEREAS, the funds provided for under said prior agreement, to which this agreement is supplemental, have been exhausted and additional funds are now required to complete said investigation and report, and it is the desire of the parties hereto that an additional sum of Twenty-Six Thousand Dollars ($26,000) shall be provided, Thirteen Thousand Dollars ($13,000) by the County and Thirteen Thousand Dollars ($13,000) by the Board;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

1. The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Thirteen Thousand Dollars ($13,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental.

2. Upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Thirteen

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Thousand Dollars ($13,000) from funds appropriated to the Board by Item 260 of the Budget Act of 1954 for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental and the State Controller will be requested to make such transfer.

3. The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the funds made available hereunder and if funds are exhausted before completion of said work, the Board and the State Engineer may discontinue said work and shall not be liable nor responsible for the completion thereof.

4. Insofar as consistent herewith and to the extent adaptable hereto, all the terms and provisions of said prior agreement to which this agreement is supplemental are hereby made applicable to this agreement and are hereby confirmed, ratified, and continued in effect.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinbefore first written.

Approved as to Form
and Procedure

/s/ H. C. Grundell
District Attorney
County of San Luis Obispo

Approved as to Form
and Procedure

/s/ Henry Holsinger
Attorney for Division
of Water Resources

Approved as to Form and Procedure

Attorney, Department
of Public Works

APPROVED:

Director of Finance

:S.H.Y.: L.F.H.: :
: Form : Budget : Value:Descript. :
DEPARTMENT OF FINANCE
APPROVED
July 30 1954.
JOHN M. PEIRCE, Director
By /s/ Louis J. Heinzer
Administrative Adviser

COUNTY OF SAN LUIS OBISPO

By /s/ John Ruskovich
Chairman, Board of Supervisors

/s/ A. E. Mallagh (Seal)
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ B. A. Etcheverry
B.A. Etcheverry, Vice Chairman

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

FRANK B. DURKEE
Director of Public Works

By /s/ Russell S. Munro (Seal)
Russell S. Munro
Deputy Director of Public Works

/s/ A. D. Edmonston
A. D. Edmonston
State Engineer

SUPPLEMENTAL AGREEMENT
BETWEEN
THE STATE WATER RESOURCES BOARD,
THE COUNTY OF SAN LUIS OBISPO, AND THE
DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, entered into as of the 1st day of May, 1956, by and between the State Water Resources Board, hereinafter referred to as the "Board", the County of San Luis Obispo, hereinafter referred to as the "County", and the Department of Public Works, State of California acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

W I T N E S S E T H

WHEREAS, the budget Act of 1952 (Chapter 3, Statutes of 1952) by Item 268.5(b) appropriated the sum of $20,000 for the initiation of a comprehensive survey of the water resources of San Luis Obispo County; and

WHEREAS, by agreement heretofore entered into as of July 1, 1953, supplemented by a further agreement entered into as of July 1, 1954, by and between the Board, the County, and the State Engineer, it was provided that the work to be performed thereunder shall consist of (1) a complete review of reports of prior investigations concerning the water resources of San Luis Obispo County, (2) field investigations and office studies to determine (a) the location, occurrence, and condition of water resources of the County, both surface and underground, (b) present water utilization including its nature, extent, and a survey of water service areas, (c) land classification survey to determine probable ultimate areas of irrigated land, (d) ultimate water requirements, (e) preliminary general plans and estimates of cost for development and utilization of local water resources of the County, (f) required supplemental water supply from outside sources, (g) possible outside sources for required supplemental supply, and (3) formulation of a report thereon; and

WHEREAS, under said agreement and supplemental agreement, the County made available the total sum of $28,000 which was matched in an equal amount by the Board for expenditure by the State Engineer in the performance of the work provided for in said agreement; and

WHEREAS, the funds provided for under said prior agreements, to which this agreement is supplemental, have been exhausted and additional funds are now required to complete said investigation and report, and it is the desire of the parties hereto that an additional sum of Five Thousand Dollars ($5,000) shall be provided, Two Thousand Five Hundred Dollars ($2,500) by the County and Two Thousand Five Hundred Dollars ($2,500) by the Board;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the County, and the State Engineer do hereby mutually agree as follows:

1. The County, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Two Thousand Five Hundred Dollars ($2,500) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreements to which this agreement is supplemental.

2. Upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Two Thousand Five Hundred Dollars ($2,500) from funds appropriated to the Board by Item 212 of the Budget Act of 1955 for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreements to which this agreement is supplemental and the State Controller will be requested to make

such transfer.

3. The Board and the State Engineer shall under no circumstancess be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the funds made available hereunder and if funds are exhausted before completion of said work, the Board and the State Engineer may discontinue said work and shall not be liable nor responsible for the completion thereof.

4. Insofar as consistent herewith and to the extent adaptable hereto, all the terms and provisions of said prior agreements to which this agreement is supplemental are hereby made applicable to this agreement and are hereby confirmed, ratified, and continued in effect.

IN WITNESS WHEREOF, the parties hereto have executed this agreement to be effective as of the date hereinbefore first written.

Approved as to Form
and Procedure

/s/ H. C. Grundell
District Attorney
County of San Luis Obispo

COUNTY OF SAN LUIS OBISPO

By /s/ John Ruskovich
Chairman, Board of Supervisors

/s/ A. E. Mallagh (Seal)
Clerk, Board of Supervisors

Approved as to Form
and Procedure

/s/ Henry Holsinger
Attorney for Division
of Water Resources

STATE WATER RESOURCES BOARD

By /s/ Clair A. Hill
Clair A. Hill, Chairman

Approved as to Form
and Procedure

____
Attorney, Department
of Public Works

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

FRANK B. DURKEE
Director of Public Works

Director of Finance

By /s/ A. H. Henderson (Seal)
A. H. Henderson
Deputy Director
May 28, 1956

S.H.Y.	A.W.		
Form	Budget	Value	Descript.

DEPARTMENT OF FINANCE
A P P R O V E D
Jun 4, 1956

JOHN M. PEIRCE, Director

By /s/ Louis J. Heinzer
Administrative Adviser

Harvey O. Banks
State Engineer

APPENDIX B

GEOLOGY AND GROUND WATER OF
SAN LUIS OBISPO COUNTY, CALIFORNIA

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TABLE OF CONTENTS

Page

TABLES

ACKNOWLEDGMENT

Many of the data presented in this report were contributed by public and private agencies, which materially assisted the geologic and hydrologic studies of San Luis Obispo County.

The following agencies contributed materially to this report:

California Department of Natural Resources, Division of Mines

California Department of Natural Resources, Division of Oil and Gas

San Luis Obispo County Surveyor and Road Commissioner

Shell Oil Company

The Texas Company

Tidewater Associated Oil Company

The voluntary and valuable cooperation received from these and other organizations, geologists, well drillers, and individuals is gratefully acknowledged.

CHAPTER B-I. INTRODUCTION

San Luis Obispo County includes an area of approximately 3,326 square miles, enclosed by surveyed lines chosen irrespective of watershed boundaries on the north and east sides. The western boundary is the Pacific Ocean, and the southern boundary is defined by the Santa Maria and Cuyama Rivers.

This appendix includes a description of the geology of San Luis Obispo County and adjacent areas with particular emphasis placed upon those geologic features which influence the occurrence and movement of ground water. Its purpose is threefold, namely:

1. To describe the geology and water-bearing properties of the various geologic formations.

2. To discuss the effects of geologic structure upon the movement of ground water and upon sea-water intrusion, and to describe briefly the history of events leading to the evolution of the principal geologic structures.

3. To describe the geologic conditions involved and the procedures followed in estimating the changes in ground water storage and estimating underflow that occurred into or out of the principal basins during selected periods of study.

The older less permeable formations which yield little water are treated briefly. They are the parent source of sediments which fill the ground water basins and delimit the ground water basins. In certain localities they affect the mineral content of the ground water and their position, in part, controls the movement and occurrence of ground water.

The permeable water-bearing formations are described in greater detail. These deposits comprise the alluvial fill of the ground water basins, the principal sources of ground water supply in the County.

Subsurface ground water geology was interpreted largely from the logs of about 300 water wells, most of which were obtained from field canvass. Drillers' logs, 93 electric logs, and descriptions of cores from oil wells were obtained from the State Division of Oil and Gas. An additional 60 logs of shot holes were provided by The Texas Company. Ground water level data and water quality analyses were collected, and in certain areas, the transmissibility and specific yield of sediments were estimated by pump testing of wells. All of these data were drawn upon freely in interpreting geologic features.

A perusal of geologic literature revealed a number of maps and reports prepared by earlier investigators covering various parts of the County. These existing data were often referred to in the preparation of this appendix and are listed in the accompanying bibliography.

During this investigation, a geologic map, shown on Plates 7A, B, and C, was prepared. It represents a compilation of portions of existing geologic maps, studies of aerial photographs, and field mapping by the Division of Water Resources in areas where previous mapping was insufficient or incomplete. There were many cases of disagreement between the various sources. The most detailed source available was used where nonwater-bearing materials were involved. Where such disagreement concerned important water-bearing materials, the conflict of data was resolved by field mapping.

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CHAPTER B-II PHYSIOGRAPHY

San Luis Obispo County is located in the South Coast Range geomorphic province (Jenkins, 1943) and consists of essentially northwest-southeast trending mountains and valleys, with a few areas approaching an east-west trend. San Luis Obispo County may be divided into mountainous areas, the Salinas structural basin, the Carrizo Plain, Coastal valleys and terraces, offshore areas, and miscellaneous areas. The County is drained by the Salinas River system in the north, coastal streams in the west, and the Santa Maria River and tributaries in the south.

Mountain Areas

The Santa Lucia Range is the major mountain range in San Luis Obispo County. It is an area of uplift which covers the western half of San Luis Obispo County. For descriptive purposes the Santa Lucia Range includes the San Luis Range and the La Panza Range, and extends southwestward across the Cuyama River into Santa Barbara County where it is known as the San Rafael and Sierra Madre Mountains. This entire mountain range is topographically rugged, reasonably consistent in geologic structure, and is in approximately the same stage of geomorphic development throughout. The mountains range from 2,000 to 4,000 feet in elevation, the highest point being McChesney Mountain at 4,054 feet in La Panza Range. In the Santa Lucia Range adjacent to the coast, the highest point is Pine Mountain at an elevation of 3,594 feet above sea level. The highest point in the San Luis Range is 1,792 feet above sea level.

Folding and faulting control the general northwest-southeast trend of mountain ranges. The Santa Lucia Range is in a mature stage of development.

Some of the ridges appear to be remnants of an old erosion surface which has been dissected by streams cutting valleys up to 2,500 feet deep. Most of the valleys in the mountains are in a youthful to early mature stage of development. A few valleys high in the mountains have been widened by erosion and contain alluvial fill deposited when streams reached a temporary base level of harder rock. Old perched stream gravels, remnants of a previous erosion cycle, are found near the San Luis Obispo-Monterey County line and in parts of the Salinas River drainage. Wider stream valleys such as the Huasna Valley system are generally developed in zones of softer rock.

The Caliente Mountains, in the southeast part of San Luis Obispo County, are generally considered as separate from the Santa Lucia Range. The Caliente Mountains have a maximum elevation of 5,104 feet above sea level, the highest point in San Luis Obispo County. The topography of the Caliente Mountains is rugged and the range has reached a mature stage of erosion. The mountains are drained by steep canyons to the Cuyama Valley on the south, to the Carrizo Plain on the north and east and to San Juan Creek on the northwest.

Coastal Valleys, Terraces, and Sand Dunes

The Santa Lucia Mountains are drained toward the ocean by several streams which have eroded deep canyons. The history of the coastal streams has been complex and is summarized in Chapter B-V. Coastal valleys with less than two square miles of drainage area generally have little or no alluvial fill. Larger streams, however, usually flow on alluvial beds formed by deposition of sands and gravels as sea level rose after the last glacial period. Marine terraces are found along most of the coast. These terraces were cut prior to the last glacial period when sea level was from 50 to 100 feet higher than at present. The terraces have been backfilled with stream gravels and alluvial fans. Recent wave erosion has removed the seaward extension of most terraces, exposing the underlying bedrock.

Sand dunes of two ages are found along the coast. The older, reddish, brush covered sand dunes are overlain by active, white sand dunes in the Nipomo Mesa and Morro Bay areas. Morro Bay itself is a tidal lagoon enclosed on the seaward side by a barrier sand bar. The lagoon is shallow and is being filled by stream deposited silt and sand, and by wind blown sand. Although complete evidence is lacking, it appears that the original area of Los Osos Valley and Morro Bay may have been eroded by a stream which drained the upper portions of the present Pismo and San Luis Obispo Creek drainage areas. Another small tidal lagoon occurs at the mouth of San Luis Obispo Creek. Marshland which is the final remnant of a tidal lagoon is found behind the active sand dunes in the area south of Pismo Beach to Black Lake, at the mouth of Arroyo Grande Valley. Parts of the marshland have been drained and used for agricultural purposes.

Salinas Structural Basin

The Salinas structural basin will be referred to in this appendix as the Salinas Basin in contrast to the term Salinas drainage basin, which refers to the area drained by the Salinas River. The Salinas Basin in San Luis Obispo County is the southern extension of a similar geologic structure in Monterey County which extends northwestward to the ocean. In San Luis Obispo County the Salinas Basin is approximately outlined by the Paso Robles formation in the Salinas River drainage area as shown on the geologic map, Plate 7A, and on the geologic cross-sections, Plate 8A.

Elevation in the Salinas Basin varies from about 500 to over 2,200 feet above sea level. Prominent geographic features included in this basin are the Cholame Hills, and parts of the Salinas River and Estrella and San Juan Creek Valleys. Topography varies from fairly flat terrace land to steep hills with up to 600 feet of relief. Generally, however, relief is less than 200 feet. The area was eroded from a relatively featureless depositional plain, and is now in a youthful to mature stage of erosion. Estrella Creek is cutting downward into the underlying sediments in a meandering valley, but does not itself meander within the valley. Most smaller streams have very thin deposits of alluvium and appear to be eroding downward at the present time. The Salinas River is underlain by about 30 feet of gravel and appears to be in a relatively stable condition, although some recent downcutting has occurred. Older eroded stream terraces and thin terrace deposits are found adjacent to larger streams indicating recurrent stages of downcutting.

The ridge tops of the Salinas Basin present a fairly flat profile which slopes very gently upward from the area near Bradley toward the Cholame Hills and the Carrizo Plain.

Carrizo Plain

The Carrizo Plain is a narrow elongated basin of interior drainage surrounded by northwest trending mountain ranges. The Temblor Range on its east side and the Caliente Range on the west drain toward Soda Lake, the center of the basin. Elevations within the plain area vary from 1,950 to 2,500 feet above sea level. The Carrizo Plain includes a hill area underlain by older eroded sediments along its northeast margin, terminal alluvial fans surrounding the flat portion of the Plain, and the central area underlain by lake deposits. The San Andreas fault extends along the entire northeast side of the Plain. This active fault has formed fault scarps, ridges, trenches, and closed depressions in the Recent alluvial fill and has offset many small streams.

Submarine Features

The only known offshore topographic mapping and bottom sample data in the San Luis Obispo County area appears on charts 5302 and 5387 prepared by the United States Coast and Geodetic Survey. These charts indicate offshore topography to be fairly smooth for some 20 miles offshore from Ragged Point in San Luis Obispo County to south of Point Sal in Santa Barbara County. Seaward extensions of present stream valleys are not evident near the shore. A former submerged valley system probably existed, but succeeding deposition of stream sediments, transported by long shore currents, and other erosional debris have now filled the earlier depressions. Most of the larger coastal valleys contain alluvial fill up to 200 feet in thickness and at depths as great as 200 feet below present sea level near their mouths; an indication of the filling of the landward portions of old stream-eroded canyons. Fill probably extends seaward until it meets the sand, silt and clay now covering the ocean floor. Other evidence of the filling of the valleys is the lack of rock outcrops at the mouths of all the larger valleys. Small submarine valleys are present about six miles west of Ragged Point, but no large submarine canyons are immediately offshore in the San Luis Obispo County area. Submarine canyons are present north and south of San Luis Obispo County. Arguello submarine canyon is located off the Santa Barbara County coast and Lucia and Sur canyons off the Monterey County coast.

Other Areas

Other physiographic features in and near San Luis Obispo County include Cholame Valley, the Temblor Range, the southern tip of the Diablo Range, Cuyama Valley, and Santa Maria Valley.

Cholame Valley is an area which has been eroded into rocks weakened by the San Andreas fault system and possibly also by depression of fault block slivers. The Cholame Valley floor is very flat near its outlet and is underlain by clays, suggesting the presence of a lake at various times in the lower part of this valley resulting from movement of the San Andreas fault near the village of Cholame. In the upper portion of Cholame Valley terrace gravels are found from 100 to 150 feet above the valley floor.

The Diablo Range extends into a small portion of San Luis Obispo County. It is generally similar to other mountain ranges in San Luis Obispo County. The Temblor Range separates the San Luis Obispo County region from San Joaquin Valley, and is moderately rugged with a maximum elevation of 3,931 feet.

Parts of Cuyama and Santa Maria Valleys are in San Luis Obispo County and have been described by Upson and Worts (1951), and Worts and Thomasson (1951).

CHAPTER B-III. GEOLOGIC FORMATIONS

General descriptions of all geologic formations and a short discussion of their role in the hydrology of San Luis Obispo County are included in this section.

The detailed geologic maps of San Luis Obispo County shown on Plates 7A, B, and C, illustrate the areal extent and distribution of formations based principally on lithology. Table B-1 presents generalized stratigraphy in San Luis Obispo County with brief descriptions of the various formations in different areas.

Basement Complex

The basement complex in San Luis Obispo County consists of pre-Franciscan plutonic and metamorphic rocks. The metamorphic rocks are exposed in limited areas along the San Andreas fault, in San Juan Creek, and in the La Panza Mountains. They are probably the equivalent of the Sur series in the Santa Lucia Range in Monterey County (Reiche, 1937; Trask, 1926). The metamorphic rocks consist of schist, marble, gneiss, and quartzite, which have been derived from sedimentary and igneous rocks.

TABLE B-1

GENERALIZED STRATIGRAPHY OF SAN LUIS OBISPO COUNTY

Pacific Coast Stages		Salinas Basin - Carrizo Plain Region	Coastal Region
Quaternary	Recent	Alluvium and terrace deposits. Sand, gravel, silt, and clay 0-130 feet thick. Yields water to irrigation wells near Salinas River. Contains poor quality water in Carrizo Plain.	Beach sand and Recent sand dunes 0-100 feet thick. Ground water not utilized due to limited areal extent. Alluvium - 0 to 200 feet of sand, gravel, and some clay. Main aquifer of Coastal Basins.
		Unconformity	Unconformity
	Upper Pleistocene	Terrace deposits. Continental gravel, sand, and clay 0-50 feet thick. Yields water to a few domestic wells.	Marine terrace deposits overlain by nonmarine alluvium. Gravel, sand, and clay 0 to 50 feet thick. Utilized by few windmills due to free drainage of ground water to ocean. Older sand dunes 0 to 300 feet thick utilized by domestic wells.
		Unconformity	Unconformity
	Lower Pleistocene and Upper Pliocene	Paso Robles formation. Nonmarine sand, gravel, clay, and calcareous beds 0 to 2,000 feet thick. Yields water to many irrigation wells in Paso Robles Basin.	Paso Robles formation. Nonmarine sand, gravel, and clay 0 to 600 feet thick. Yields adequate water supplies to a few irrigation and domestic wells. Careaga sand beneath Nipomo Mesa, but not exposed in San Luis Obispo County. Water-bearing.
		Unconformity	Unconformity
Tertiary	Pliocene	Etchegoin, Jacalitos, Pancho Rico, and other formations. Marine and nonmarine gravel, sand, and clay 0 to 2,000 feet thick. Generally nonwater-bearing except in local areas near outcrop of permeable beds. Contains poor quality water at depth.	Pismo (or "Santa Margarita") formation. Marine conglomerate, sandstone, and siliceous and clay shale, up to 3,200 feet thick. Generally nonwater-bearing, but permeable lenses yield water to domestic wells.
		Unconformity	Unconformity

GENERALIZED STRATIGRAPHY OF SAN LUIS OBISPO COUNTY
(continued)

GENERALIZED STRATIGRAPHY OF SAN LUIS OBISPO COUNTY
(continued)

Pacific Coast Stages		Salinas Basin - Carrizo Plain Region	Coastal Region
Tertiary	Miocene	Santa Margarita, Monterey, Sandholdt, and Vaqueros formations, continental sediments and some interbedded volcanic rocks 0 to 7,000 feet thick. Mostly marine and nonmarine conglomerate, sandstone, and shale. Generally nonwater-bearing but wells obtain water from fractures and permeable sandstone lenses.	Monterey and Vaqueros formations. Marine shale and sandstone up to about 9,000 feet thick. Up to 2,000 feet of volcanic flows interbedded with sediments in Arroyo Grande Region. Generally nonwater-bearing but yields some water to windmills and domestic wells.
			——Unconformity——
	Oligocene	Berry, Simmler, and other formations. Nonmarine conglomerate, sandstone, and shale up to 2,000 feet thick. Nonwater-bearing.	Missing or not reported.
	Eocene and Paleocene	Marine sandstone, conglomerate, and siltstone. Nonwater-bearing.	Missing or not reported.
		——Unconformity——	
Cretaceous		Marine sandstone, conglomerate, and shale up to 14,000 feet thick. Nonwater-bearing.	Marine sandstone, shale, and conglomerate up to 14,000 feet thick. Nonwater-bearing.
		——Unconformity——	——Unconformity——
Jurassic (?)		Knoxville and Franciscan formations. Marine sandstone, shale, conglomerate, chert, and associated volcanics and intrusives. Nonwater-bearing.	Knoxville and Franciscan formations. Marine sandstone, shale, conglomerate, chert, and associated volcanics and intrusives more than 10,000 feet thick. Fractures yield water to windmills; otherwise nonwater-bearing.
		——Not in contact——	
Pre-Franciscan or Pre-Cretaceous		Basement complex. Granitic and metamorphic rocks. Fractures and weathered rock yield some water to windmills; otherwise nonwater-bearing.	Not exposed.

The largest area of plutonic rock within San Luis Obispo County is located in the La Panza Range, a smaller area is exposed northwest of Paso Robles, and several very small exposures are located along the San Andreas fault and in the faulted area along San Juan Creek. Granite is the most common of the plutonic rocks which also include granodiorite and quartz diorite (Anderson and Martin, 1914). The texture of the rocks varies from equigranular to porphyritic. They are intensively faulted, and contain numerous aplite and pegmatite dikes, as well as secondary quartz and calcite veins.

Weathered granitics supply water to domestic and stock wells in the La Panza Range and in the area northwest of Paso Robles. The weathered rock in some places yields as much as 50 gallons per minute to wells, but specific capacity of wells is usually less than one gallon per minute per foot of drawdown. Fractures within unweathered granitics often concealed beneath the weathered zone probably supply water to some wells. Wet weather springs in the weathered granitics are common in the La Panza Mountains.

Jurassic System

The Franciscan and Knoxville formations or probable Jurassic age (Taliaferro, 1943a, Easton and Imlay, 1955) underlie a considerable portion of the Santa Lucia Mountains. The formations weather deeply and form more or less rounded hills and mountains with scattered knobs of hard rock. Landslides and slumps are common in areas of Franciscan rock.

The Franciscan and Knoxville formations in San Luis Obispo County are generally similar and consist of more than 10,000 feet of highly folded and faulted sandstone, shale, and minor conglomerate and chert lenses. Sandstones are typically highly fractured and contain both calcite and quartz veins. Small bodies of glaucophane schist are found in the Franciscan formation. The

Franciscan and Knoxville sediments contain partially altered interbedded basalts and agglomerates as well as intrusive diabase and gabbro. These igneous rocks have not been shown separately on the geologic map. Pillow structure, flow structure, and vesicles have been observed in the flows. During or soon after deposition, the Franciscan and Knoxville formations were intruded by peridotite or pyroxenite in the form of sheets, dikes, and sills, which subsequently were altered to serpentine. During later folding and faulting some serpentine bodies have been squeezed into the Knoxville and possibly into the Lower Cretaceous rocks. All of these rocks have been intruded by Miocene volcanics as plugs and dikes.

A few windmill wells have been drilled into the Franciscan formation, but have yielded only small quantities of water. Ground water occurs in the weathered portion of the formation and in joints and fractures of unweathered rock. Springs are quite common, especially in the high rainfall areas near the coast. Some springs have flows as great as one or two second-feet, but many dry up during the summer.

Cretaceous System

Rocks of the Cretaceous system are found in the Santa Lucia Range, the Diablo Range (Taliaferro, 1944), the Temblor Range, and a small part of the Caliente Range. In the Santa Lucia Range the rocks have been called the Marmolejo, Jack Creek, and Asuncion formations by Taliaferro (1944).

Cretaceous formations consist of up to 14,000 feet of marine sandstone, shale, siltstone, limestone, and conglomerate. The conglomerate beds contain pebbles and cobbles of pre-Franciscan quartz, porphyry, and feldspar porphyry, quartzite, chert, recrystallized rhyolite, schist, apile, pegmatite, and granodiorite, as well as chert, basalt, diabase, gabbro, serpentine, sandstone, limestone, and shale from Franciscan and Knoxville formations.

The Cretaceous sediments seldom contain quartz veins but calcite veins are fairly common. They do not contain contemporaneous intrusive or extrusive volcanic rocks, but have been affected by cold reintrusions of serpentine and Miocene igneous intrusives.

Faulting of Cretaceous sandstone has created fractures forming conduits for the many flowing springs. These fractures and also the more permeable sandstone yield a small amount of water to a few domestic and stock wells.

Paleocene-Eocene Series

Rocks of Paleocene and Eocene age are found in limited areas in the Santa Lucia Range, in the southern tip of the Caliente Mountains, and in the Mount Diablo and Temblor ranges. These rocks consist of marine sandstone, siltstone, conglomerate, and shale.

It is not known whether any wells obtain water from Eocene or Paleocene rocks, or whether any springs are found in them in San Luis Obispo County.

Oligocene Series

Rocks of Oligocene age have been poorly delimited and may include sediments of Eocene or Miocene age. Taliaferro (1944) reports that the Paleocene-Eocene rocks west of San Miguel are overlain by a thin red sandstone of pre-Vaqueros age. Sediments of probable Oligocene age are reported northeast of Stanley Mountain near the Santa Barbara County line (Taliaferro 1943b). In the Caliente Range the Simmler formation of probable continental origin consists of about 3,000 feet of dark red sandstone with basal conglomerate (Dibblee, 1952). Hudson and White (1941) report a 1,000 foot section of chocolate brown siltstone containing Oligocene vertebrate remains in the Temblor Range.

Around the edge of and beneath the Salinas Basin there are continental conglomerates and sandstone, here called the Berry formation, up to about 2,000 feet thick, which lie upon granitic and Cretaceous rocks and are overlain in turn by marine Miocene sediments. The age of these rocks is in doubt due to lack of fossil evidence, but they are included with the Oligocene in this report.

A few stock and domestic wells and springs were noted to be obtaining water from Oligocene sediments in San Luis Obispo County. Ground water probably occurs in fractures and in more permeable lenses in the sandstone and conglomerate.

Miocene Series

Rocks of Miocene age have probably covered most of San Luis Obispo County in the geologic past. Conditions of deposition during this period were complex, resulting in a rather confusing and still poorly known series of formations.

Formations of Miocene age include the Vaqueros formation, Sandholdt shale, Monterey and Temblor formations, the Soda Lake shale, Painted Rock sandstone, and the Santa Margarita formation. These formations consist of marine white and gray sandstone, siltstone, conglomerate, clay shale, siliceous and diatomaceous shale, and chert. Unnamed formations of Miocene age are also found on the east side of San Luis Obispo County and consist of white, red, and green nonmarine sandstone, siltstone, conglomerate and shale.

Up to 2,000 feet of volcanic material consisting of basalt and andesite flows, agglomerate and rhyolite are interbedded with the Vaqueros and

Monterey formations in the Huasna Creek-Arroyo Grande area and in the Caliente Range. Sills of analcite diabase and plugs of rhyolite porphyry and andesite porphyry, which are probably of middle or lower Miocene age, are found in the Santa Lucia Range and to a minor extent in the Caliente Range (Taliaferro, 1943b). Volcanic rocks of similar age are described from the west side of the Salinas Basin at Pinnacles National Monument, but are unknown in the Salinas Basin in San Luis Obispo County. Plugs and sills of porphyry form a series of prominent steep hills extending from Morro Rock at Morro Bay to San Luis Obispo.

The formations of Miocene age are generally nonwater-bearing, but a well was observed which obtains about 500 gallons per minute from Santa Margarita sandstone near San Juan Creek. Other wells in the area east of Paso Robles obtain up to 300 gallons per minute from fractured Monterey shale. Stock or domestic wells obtain limited amounts of water from all other Miocene formations. Springs associated with faults, weathered rock and permeable zones are common in areas of high precipitation. Most of the Miocene formations contain water of poor quality at depth where they have been penetrated by oil wells.

Lower Pliocene Series

Formations of lower Pliocene age include the Etchegoin and Pismo formations. The Pismo formation has also been called the Santa Margarita formation but is apparently mostly of Pliocene age. It consists of marine conglomerate, sandstone, and clayey and siliceous shale. The Pismo formation is about 3,200 feet thick and contains large amounts of bituminous material. Domestic wells obtain up to 50 gallons per minute from the sandstones. The water is generally of good quality in shallow wells but may be poor at depths greater than 300 feet.

The Etchegoin formation described in this report includes the Pancho Rico and Jacalitos formations reported by other authors. It is up to 2,000 feet thick and is found only in and around the Salinas Basin and in the Temblor Range. The formation varies considerably from marine shale and sand to gravel, sand, and clay probably laid down in brackish water and includes some non-marine beds. Calcareous lenses and beds occur at different horizons. The gravels generally consist of chert, granitic, volcanic, sandstone and siliceous shale pebbles up to two inches in diameter. Most of the Etchegoin underlies the Paso Robles formation in the Salinas Basin. Electric logs of oil wells indicate that most of the Etchegoin formation contains water of poor quality, but in some areas, especially near outcrops, part of the Etchegoin contains fresh water. A few domestic and stock wells and one or two small irrigation wells obtain limited amounts of water from the Etchegoin formation in and around Salinas Basin.

Nonmarine Pliocene sand, gravel, and clay are found along the San Andreas fault near the Carrizo Plain. These appear to be water-bearing but quality of the water is unknown and may be poor.

Pliocene-Pleistocene Series

The most important water-bearing formation in San Luis Obispo County is the Paso Robles formation of upper Pliocene and Pleistocene age. The Paso Robles formation is represented east of the San Andreas fault in part by the Tulare formation which is essentially the same age and has been affected by the same geologic events. The Careaga sand, also deposited during this period, is encountered by oil wells in Nipomo Mesa, but is not exposed on the surface in San Luis Obispo County. In Santa Barbara County the Careaga sand is pentrated by some water wells.

A general description of the Paso Robles formation is hereinafter presented, but will be discussed in more detail under the descriptions of the ground water basins where the formation occurs. The Paso Robles formation occurs in the Salinas Basin, in the San Luis Obispo-Edna area and in the Arroyo Grande-Nipomo Mesa area. The formation consists of sand, gravel, clay, minor calcareous beds, and at least one tuff bed. The Paso Robles formation is composed of alluvial fan deposits, lake deposits, and probably flood plain deposits. Individual beds are generally highly lenticular due to scour and fill and lateral gradation. The degree of sorting of individual beds varies from good to poor. Debris in the gravels consists of siliceous shale, sandstone, volcanic rocks, chert, and in some areas granitic rock. Where siliceous shale predominates, the gravels are usually poorly sorted and generally have poor water-bearing characteristics, compared to areas where gravels contain mostly harder rocks.

The Paso Robles formation has been divided into upper and lower units in the Salinas Basin as shown on Plate 7A. These units are only approximately delineated on the geologic map. The two units are separated in areas of outcrop by an erosional unconformity but cannot be differentiated in well logs. In general, the lower Paso Robles formation contains fewer siliceous shale pebbles than the upper and is locally highly folded, whereas the upper has been only gently warped. Part of the lower Paso Robles formation probably is equivalent to the San Joaquin formation of the San Joaquin Valley. The lower and upper Paso Robles formations contain some marine fossils which have been eroded from older formations, principally the Santa Margarita formation. Other workers have reported marine fossils in the Paso Robles formation, but very little, if any, of the Paso Robles, as shown on the geologic map and in the cross sections, is actually marine. Wood fragments are rarely found in the Paso Robles formation, but fresh water fossils of the type found in modern streams have been found in many places in the formation.

The lower Paso Robles formation in the Salinas Basin may have been deposited by streams which drained the Santa Lucia Range and flowed east and north across the present San Andreas fault. Fairly thick bentonitic clays interbedded with coarse gravels near the San Andreas fault may indicate that the drainage was interrupted by movement of the fault during deposition. The lower Paso Robles formation is thickest west of the San Andreas fault near the Carrizo Plain and Cholame Valley, indicating that this area was either down-faulted during deposition or that the formation now appears thicker because of folding.

The Paso Robles formation in the San Luis Obispo-Arroyo Grande area is represented by about 200 feet of nonmarine sand, gravel, and clay. In the Carrizo Plain most of the nonmarine sediments are probably correlative with the Paso Robles and Tulare formations.

Upper Pleistocene Series

Formations of upper Pleistocene age include the Orcutt formation of the Santa Maria Valley area, terrace deposits, and old sand dunes. The Orcutt formation and older sand dunes are essentially the same for water-bearing purposes. The sand dunes are simply the wind deposited equivalent of parts of the stream-deposited Orcutt formation. The sand dunes generally overlie the Orcutt and generally represent the last phase of deposition of that formation.

Older sand dunes are also found in the Morro Bay area where water well logs indicate that they are underlain by clay and gravel. This clay and gravel may be either the Orcutt or the Paso Robles formation. The Orcutt formation is included with the older sand dunes on the geologic map on Plate 7B.

Marine and stream terrace deposits are of upper Pleistocene age. Many stream terraces are simply erosion surfaces or have such thin deposits that they are considered insignificant, and have not been shown on the geologic map. The marine cut coastal terrace varies from 20 to 100 feet above sea level upon which 10 to 50 feet of sediments have been deposited. The terrace deposits are primarily alluvial fan deposits of sand, gravel, and clay, but some thin basal lenses are of marine origin.

Recent Series

Alluvium of Recent age is limited to valley floors and consists of sand, gravel, and clay. In the Salinas Basin, alluvium averages about 30 feet in thickness in the Salinas River, but in most smaller valleys it appears to be only 5 or 10 feet thick.

In the coastal area the alluvium has filled old valleys which were eroded when sea level was about 300 feet lower than at present during the last glacial age. Similar events have occurred along most of the California coast. Thickness of alluvium in the coastal valleys varies from zero to nearly 200 feet. In very recent times streams have cut into the alluvial fill and five or ten feet of sand and gravel has been deposited in these cuts.

Recent sand dunes found along the coast are white in color and though generally bare, have a light brush cover in some areas. They are easily differentiated from the older sand dunes which have a heavy grass or brush cover, a fairly well developed soil, and are red or brown colored at the surface and to depths of 50 feet or more.

CHAPTER B-IV. STRUCTURAL GEOLOGY

Faulting and folding in San Luis Obispo County generally trend in a northwest-southeast direction. The Salinas Basin and the Carrizo Plain are essentially downfaulted or folded areas between the anticlinal Santa Lucia Range and the San Andreas fault. Cuyama and Santa Maria Valleys are synclinal in nature. The Temblor and Mount Diablo Ranges are essentially anticlinal.

The principal fault system in San Luis Obispo County is the San Andreas. Another major system is a series of more or less parallel faults in the Santa Lucia Range, one zone of which has been called the Nacimiento fault. Most faults of this system cannot be traced for great distances, as they either disappear or are replaced by another fault. The only other known major fault system is a discontinuous series of thrust and normal faults separating the Caliente Range and the Carrizo Plain from the La Panza Range. Faults and folds of hydrologic significance are included in the description of ground water basins.

CHAPTER B-V. GEOLOGIC HISTORY

The geologic history of San Luis Obispo County has been very complex. During late Mesozoic and Tertiary times, portions of the area have been repeatedly covered by the sea and then uplifted, while other portions have been below sea level a much greater part of the time. A few areas have been generally uplifted so that sediments were not deposited on them. The Tertiary history of San Luis Obispo County is closely related to the history of a larger region which includes most of Santa Barbara and Monterey Counties and parts of the other adjacent counties.

Marine sediments of Jurassic, Cretaceous, Eocene, Miocene, and Pliocene age were deposited in portions of the Santa Lucia, Temblor and Mount Diablo Ranges. Nonmarine Oligocene beds may be found in these areas also. Nonmarine Oligocene, Miocene, and Pliocene as well as marine Miocene and Pliocene sediments were deposited in the Salinas Basin, the Carrizo Plain, and the Caliente Range. Nonmarine Pleistocene and Recent sediments have been deposited in most areas in the county. The absence of Jurassic, Cretaceous or Eocene sediments in the Salinas Basin is of interest as it indicates that this area was above sea level for some time before the beginning of deposition of the nonmarine sediments of probable Oligocene age.

As deposition of Pliocene marine sediments began, the Santa Lucia, Diablo, and Temblor Ranges began rising until the marine embayments of the Santa Maria Valley and the Salinas Basin regions were filled and finally lifted above sea level. The Paso Robles formation was deposited in late Pliocene and early Pleistocene time over the older sediments in these areas as alluvial fan and flood plain deposits. Folding of all sediments continued and reached maximum intensity in mid-Pleistocene time. It is possible that the older portions of the Paso Robles sediments in the Salinas basin were deposited by streams draining northeastward across the San Andreas fault toward the San Joaquin Valley. Thick clay beds near the San Andreas fault may indicate swamp or lake conditions caused by movement of the fault. The Paso Robles formation was folded, faulted, and eroded. In the Salinas Basin an unconformity has been noted within the Paso Robles formation which conveniently divides it into upper and lower units. It is possible that this unconformity represents the mid-Pleistocene orogeny, but lack of fossil evidence makes it possible that the unconformity may have occurred in lower Pleistocene or even in Pliocene time. In the Salinas Basin the upper Paso Robles formation filled in the area which had been eroded into the lower Paso Robles formation and eventually formed a broad flat alluvial plain which probably drained northwest toward the ocean.

In the San Luis Obispo, Arroyo Grande, and Nipomo Mesa areas, the Paso Robles formation was folded and partially removed. In the Morro Bay and Arroyo Grande areas remnants of upper Pleistocene stream deposits and sand dunes are found.

Erosion of the Paso Robles formation in the Salinas basin has continued to the present time, but large terraces testify to relatively stable periods.

In the coastal area marine terraces up to 300 feet above sea level, and possibly up to 900 feet, indicate that the area has been uplifted considerably during upper Pleistocene time. The lowest upper Pleistocene marine terraces and older formations were eroded to depths of up to 200 feet below sea level as a result of lowering of sea level during the last glacial period. Similar events have occurred on the coast of Santa Barbara County and have been described by Upson (1949). After the last glacial period, sea level rose and the coastal valleys were backfilled with stream deposits and with some lagoonal deposits near the ocean. More recent events along the coast include erosion of headlands and transport of sand to protected areas where beach sands have been deposited.

A fairly recent downcutting of most streams in San Luis Obispo County has occurred. The reason for this is uncertain, but probably includes both climatic and cultural factors. Earthquakes in the Santa Lucia Mountains and along the San Andreas fault testify to present activity of faults in the San Luis Obispo County area.

CHAPTER B-VI. DESCRIPTION OF GROUND WATER BASINS

Discussed in the following paragraphs are nineteen ground water basins in San Luis Obispo County, identified during the course of this investigation. The boundaries of these basins are shown on Plates 9A, B, and C. The Cuyama and Santa Maria ground water basins are not described in this bulletin since they are mostly in Santa Barbara County, and are described in considerable detail by Upson and Worts (1951), and by Worts and Thomasson (1951).

The boundaries of ground water basins in most instances conform with geologic features, such as contacts between permeable and impermeable formations, fault zones of low permeability or changes in subsurface lithology which affect movement or mode of occurrence of ground water. These boundaries were established from available data including well logs, areal geology, and hydrologic observations.

Most ground water basins in the County consist of unconsolidated sediments or alluvium and are of two types. These are: (1) The simple basin in which ground water occurs in a single unconfined body, and (2) the complex basin in which ground water occurs in more than one aquifer. Most of the smaller ground water basins along the coast and in the higher mountains are essentially simple types consisting simply of alluvial fill. The larger ground water basins in San Luis Obispo County are complex, having more than one aquifer, and are affected, at least in part, by folding and faulting.

Ground Water Storage and Subsurface Flow

The purpose of these paragraphs is to explain the procedures used to determine quantitative estimates of ground water storage and subsurface flow. Results of the study are summarized in Tables B-4 through B-8 and are discussed in Chapter II of the foregoing report.

Ground Water Storage

Ground water is stored within the interstices of sediments and in cracks or fractures of solid rocks. The changes in ground water storage occurring over selected periods of study were generally not estimated due to lack of historical data on ground water level fluctuations. A certain portion of the total storage can be considered usable storage capacity, but this amount is uncertain in most basins due to lack of data. In general, the estimating procedures required: (1) A determination of total volume of saturated sediments and, (2) an estimate of the percentage of this volume that contained extractable ground water. The first item was obtained by computing the volume of sediments that lay between the water table and the bottom of the basin. The second item was obtained by evaluating the average weighted specific yield of the sediments by analysis of available well logs.

The specific yield of a sedimentary deposit is the ratio between the volume of water which a saturated sample of that material will yield by gravity and the volume of that sample, customarily expressed in per cent. During the South Coastal Basin Investigation, the Division of Water Resources conducted extensive field and laboratory investigations for the purposes of assigning specific yield values to various types of material appearing in well logs. These procedures are described in Bulletin No. 45 "Geology and Ground Water Storage Capacity of Valley Fill" (Division of Water Resources, 1934). With slight variations, the values determined in this earlier work were adopted for computing the change of storage estimates presented here.

The task of assigning specific yield values to the sediments appearing in logs was simplified by dividing all basin sediments into eight general categories. These included soil, clay, clay and sand, clay and gravel, tight sand, sand, tight gravel, and gravel. Sand, gravel, and clay, which constitute the bulk of the basin sediments, were generally found to be well differentiated on the drillers' logs. Combinations of these materials, however, were frequently described by such unique terms as "ooze", "muck", "cement", etc. Materials so described were placed, based on the judgment of a geologist, into one of the above eight categories. Table B-2 indicates specific yield values assigned to the general categories of material encountered. The Paso Robles formation is generally more compacted and weathered than the alluvium and some specific yield values were lowered accordingly.

TABLE B-2

SPECIFIC YIELDS OF SEDIMENTS

Material	Specific yield (per cent)	
	Alluvium	Paso Robles formation
Soil, including silty clay	5	5
Clay, including adobe and hard pan	3	3
Clay and sand, including sandy silt	5	5
Clay and gravel	7	7
Sand	25	20
Tight sand, including cemented sand	18	15
Gravel, including gravel and sand	21	18
Tight gravel, including cemented gravel	14	13

Subsurface Flow

Subsurface flow was estimated in all cases by the slope-area method. The slope-area method is based on the commonly used form of Darcy's law, Q=PAI, where Q equals subsurface flow in gallons per day passing through the cross-sectional area A in square feet; P is permeability in gallons per day per square foot of cross-sectional area; and I is slope of water table at the cross-section in feet per foot. In order to determine the permeability used in subsurface flow estimates, well pump operation tests were conducted. Data from these well pump operation tests also served as a check of the specific yield values used in the storage calculations. Table B-3 presents results of permeability well pump tests conducted during the investigation. Analyses of the well pump tests were based on non-steady flow equations described by Jacob and Cooper (1946), and Wenzel (1942). Both time-drawdown and recovery methods were used as field conditions permitted. Storage coefficient is defined as the volume of water which can be obtained from a unit volume of saturated sediments by lowering the water level one foot. In an unconfined aquifer storage coefficient is approximately equal to specific yield. In a confined aquifer storage coefficient is very small since it is related to elasticity of the aquifer.

TABLE B-3

RESULTS OF PERMEABILITY WELL TESTS

Well	Formation	Method of test	Transmissibility g.p.d./ft.	Thickness feet (perforated)	Permeability g.p.d./ft.^{2}	Storage coefficient
			Paso Robles Basin			
28S/13E-31K2 (Van Horn)	Alluvium	Drawdown	145,000	35	4,150	.238
26S/12E-33Q5 (City Paso Robles)	Alluvium	Drawdown	77,500	19	4,050	over .10
27S/15E-11C1 (Sinton)	Paso Robles	Drawdown	1,020,000	250	4,100	1.3×10^{-3}
27S/15E-23M1 (Sinton)	Paso Robles	Drawdown	70,000	295	240	3.2×10^{-5}
24S/11E-34P1 (Camp Roberts)	Paso Robles	Recovery	12,900	114	113	---
24S/11E-35E1 (Camp Roberts)	Paso Robles	Recovery	14,707	93	1,580	---
24S/11E-25N1 (Camp Roberts)	Paso Robles	Recovery	6,365	43	148	---
			Arroyo Grande Basin			
32S/13E-22Q2	Alluvium	Recovery and Drawdown	100,000	50	2,000	.09
32S/13E-3D24 (Oceano Water Co.)	Paso Robles	Recovery and Drawdown	22,000	60	370	5.0×10^{-3}
			Nipomo Mesa			
11N/35W-7A1 (Stauffer Chemical Co.)	Paso Robles	Drawdown	6,000	30	200	6.3×10^{-3}

Ground Water Basins Within Upper Salinas Unit

The most important ground water basin in the Upper Salinas Unit is the Paso Robles Basin. The only other ground water basin given detailed consideration in this bulletin has been designated as Pozo Basin. Principal features of the two ground water basins in this unit are summarized in Table B-4.

TABLE B-4

SUMMARY OF GROUND WATER BASIN CHARACTERISTICS
UPPER SALINAS UNIT

	Paso Robles Basin	Pozo Basin
Total surface area, in acres	580,700	3,600
Surface area of Paso Robles formation, in acres	562,100	0
Surface area of alluvium, in acres	30,300	3,600
Depth and thickness of Paso Robles formation, in feet	0-3000	---
Depth and thickness of alluvium, in feet	0- 130	0-30
Depth of irrigation wells, in feet		
Maximum	1,200	230
Estimated average	400	50
Depth to water in wells, in feet		
Maximum	290	110
Minimum	0	5
Yield of irrigation wells, in gpm		
Maximum	3,300	230
Estimated average	500	100
Specific capacity, in gpm/foot of drawdown		
Maximum	111	---
Estimated average	15	---
Number of irrigation wells, 1954	220	17
Estimated average specific yield, in per cent	8	15
Estimated average basin depth, in feet	900	20
Estimated saturated storage capacity, in acre-feet	Several million	2,000
Occurrence of ground water	Unconfined and confined	Unconfined

Paso Robles Basin

The Paso Robles Basin, shown on Plate 9A, is limited by the extent of the Paso Robles formation and alluvium except where the drainage divide separates it from the lower Salinas Valley and Carrizo Plain Hydrologic Units. Extent of the formations is shown on Plate 7A. Outlying areas of water-bearing formations which are thin or limited in areal extent are not included in the Paso Robles Basin. Well log sections of the Paso Robles Basin are shown on Plate 8A.

Description of Formations. For purposes of this report all formations older than the Paso Robles formation are considered to be essentially nonwater-bearing. These formations range in age from Pliocene to pre-Creataceo and include marine and nonmarine sediments, as well as granitic and metamorphic rocks. These nonwater-bearing formations underlie and flank the water-bearing Paso Robles formation and alluvium.

Water-bearing formations consist of Recent and upper Pleistocene alluvial deposits and the Paso Robles formation of Plio-Pleistocene age. The alluvium consists of gravel, sand and clay and is found in most stream valleys in the Upper Salinas Unit. It is generally very thin (less than 30 feet) in the minor tributaries. The deepest alluvial deposits are found in places along the Salinas River where depths as great as 130 feet have been found, although alluvium averages only about 30 feet along most of the Salinas River. Characteristics of alluvium in Cholame Valley are relatively unknown because of the lack of well logs. Alluvium there is roughly estimated to be 100 feet thick and consists of sand, gravel, and clay.

The Paso Robles formation consists of up to 2,000 feet of sand, gravel, silt, clay, calcium carbonate and gypsum cemented beds, occasional fresh water limestones, and volcanic ash beds. The clays are yellow, red, brown, blue, green, and gray in color. Some of the blue and green clays in the eastern portion of the Paso Robles Basin are highly bentonitic suggesting that some volcanic ash may have been deposited with the clay. Disseminated gypsum is fairly common in silt and sand beds on the east side of the basin. The sand and gravel beds are commonly torrentially bedded, and scour and fill features are observed in nearly every outcrop. Individual beds cannot be traced for more than about a mile on the surface or in closely spaced wells. Some gravels and clays up to 10 or 15 feet thick have been observed on the outcrop to pinch out in a distance of 300 feet. All of these features may be attributed to deposition by meandering streams and rivers on a flood plain or on alluvial fans. Many of the clays, silts, and limestones appear to have been deposited in small lakes, but many clays and silts are simply flood plain deposits. Many of the calcium carbonate cemented beds resemble fossil hardpans.

Small fragments of plant remains and a few fresh water shells have been found in the Paso Robles formation. A few reworked marine shells and reworked microfossils were also noted. No plant remains are known to have been recorded by well drillers or geologists in the Paso Robles formation in the Paso Robles Basin.

The Paso Robles formation is underlain unconformably in most outcrop areas by the Etchegoin formation (also known as the Pancho Rico or Jacalitos formation) which consists of sand, gravel, clay, and silt deposited under marine conditions or in brackish water. The contact between the Paso Robles and the Etchegoin formations is often difficult to detect on the outcrop and in well logs. Electric logs of oil wells, however, indicate that the Etchegoin formation in most areas contains brackish water while the Paso Robles formation contains fresh water. The upper portion of the Etchegoin formation, although often containing marine shells, is generally similar to the Paso Robles lithologically. The deeper Etchegoin is nearly all shale and is fairly distinctive in drillers' logs and in electric logs.

There is evidence of a major unconformity within the Paso Robles formation with the older, deeper, more folded portion generally yielding more water to wells than the younger, less folded portion. The older Paso Robles generally contains more pebbles from pre-Monterey formations (granite, chert, conglomerate, and green sandstone) and the younger portion generally contains mostly Monterey shale pebbles, indicating that, while the Paso Robles formation was being deposited, the surrounding hills were being uplifted and eroded. The unconformable relationship can be observed near the town of Cholame, east of Atascadero, north of San Miguel along the Salinas River, west of San Miguel along the Nacimiento River, and southeast of Shandon along San Juan Creek. Much of the Monterey formation must have been covered by post-Monterey formations or must have underlain lowland areas during deposition of the older Paso Robles formation. It is possible that the older Paso Robles formation was deposited by streams flowing toward the north and east, that is, toward the San Joaquin Valley and that present drainage down the Salinas Valley was not initiated until some time during deposition of the younger Paso Robles formation.

The older Paso Robles formation is generally exposed in anticlinal areas, and the two members are easily differentiated where the unconformity with the younger Paso Robles is exposed. It is usually difficult to trace this unconformable contact in the field over long distances, and it is only approximately shown on the geologic map.

The older Paso Robles formation is locally steeply folded and faulted, and overturned beds have been observed. Where older and younger Paso Robles both have gentle dips it is impossible to differentiate them by structure alone. Clays of the older Paso Robles formation are generally blue or green, but may also be yellow or reddish. The older Paso Robles formation is up to about 2,300 feet in thickness. It contains at least one volcanic ash bed but many clays are highly bentonitic, especially near the San Andreas fault, indicating that they may also contain volcanic ash.

The younger Paso Robles is generally more silty, more yellowish or reddish in color, and less regularly bedded than the older. The younger Paso Robles generally dips only one or two degrees, but 10 degree dips are found near some folds. Large areas underlain by the younger Paso Robles consist of practically flat beds which overlap older Paso Robles and nonwater-bearing formations on the edges of the basins. The younger Paso Robles is approximately 500 to 700 feet thick, but in many areas only 100 to 300 feet of this formation is below the water table. The younger Paso Robles formation shown on the geologic map also includes some terrace deposits and older alluvium which are too thin or discontinuous to be of significance to ground water and which are very difficult to differentiate from the Paso Robles formation itself.

<u>Structure of Water-Bearing Formations</u>.- The alluvium does not appear to have been faulted or folded. The Paso Robles formation, in general, is fairly flat lying but is well folded and faulted in some areas. Folding can be observed in outcrops of the Paso Robles formation, but faulting is difficult to detect due to the lack of consolidation of the formation. Faulting has been detected in some outcrops and in oil wells and may be inferred in a few areas from the presence of sulphur springs and from physiographic evidence.

The known faults cutting the Paso Robles formation and possibly acting as barriers to movement of ground water are the San Andreas, San Juan, and Paso Robles faults. Several smaller faults also cutting the Paso Robles formation are shown on the geologic map. In the case of the major faults, the uplifted nonwater-bearing rocks appear to be more important as barriers to the movement of ground water than the fault itself.

Folding of the Paso Robles formation has considerable effect on the occurrence and movement of ground water. In some areas the Paso Robles formation has been raised by folding and has been eroded so that the beds are suitably exposed to receive direct replenishment by percolation of stream flow and rainfall. Anticlinal areas of some importance include the Bradley and Huerhuero anticlines, the Cholame Hills anticlinal area, and the Paso Robles fault and San Juan fault anticlinal areas. The area in the south central part of the Paso Robles Basin is essentially a northward-dipping homocline which has been called the Highland homocline (from Highland School District). After percolation the water moves toward pumping areas where the Paso Robles sediments are buried, such areas including the Bradley, San Miguel and Huerhuero synclines and the broad, flat-bedded area in the region near Shandon. The folds of the Paso Robles formation beneath areas of alluvium probably result in interchange of water between the two formations when ground water gradients are favorable to such interchange.

Occurrence and Movement of Ground Water. Ground water occurs in the alluvium and in the Paso Robles formation in the Paso Robles Basin. Ground water in alluvium of the Salinas River is unconfined. In Cholame Valley the northern portion appears to be unconfined but the southern portion is probably confined.

Within the Paso Robles formation, occurrence of ground water is rather complex due to lenticularity of aquifers, folding of the formation, and the presence of older and younger members of the formation.

Water levels in various aquifers in any area are generally at different elevations. As far as can be determined, the shallower aquifers generally have higher water level elevations than deeper aquifers, indicating a slow downward movement of ground water. In the few areas where water level in wells is above the ground surface (areas of flowing wells), the shallow aquifers generally have a lower water level elevation than the deeper wells, indicating slow upward movement of ground water. Areas of upward movement of ground water include portions of Cholame, Estrella, and Huerhuero Creek valleys. Hence, one may visualize movement as generally downward in topographically high areas and upward in topographically low areas which have been incised by stream erosion. The higher topographic areas, which comprise most of the Paso Robles Basin, may then be considered essentially free ground water areas. Through the period of this investigation the low areas have acted as pressure areas, as evidenced by flowing wells, but if the ground water level of the entire basin should be lowered below the topographic lows, then the vertical movement in these areas would most likely be downward. Under such conditions the areas could be considered as an area of free ground water. In the area of the Huerhuero and San Miguel synclines a few deep wells have higher water levels than the shallow wells even though located in topographically high areas. In this case, it is believed that deeper wells tap aquifers which rise higher on the flanks of adjacent anticlines, and as a result, have a greater head and a higher water level elevation.

Most good irrigation wells in Cholame Valley are located in the northern portion of the valley and obtain water from the Paso Robles formation.

It is most probable that the sands and gravels of the overlying alluvium are in hydrologic continuity with the Paso Robles formation. The alluvium in the Salinas River is also in hydrologic continuity with the underlying Paso Robles, especially where the latter has been folded. As shown in Plate 9A, ground water in the Paso Robles Basin moves from the hill areas toward the larger streams, that is, toward Estrella Creek and the Salinas River and thence to the north and out of the Paso Robles Basin into the lower Salinas Valley.

Ground water in the Salinas River alluvium is apparently completely replenished nearly every year by percolation of river flow. Additional recharge includes percolation of precipitation and excess irrigation water, and an unknown quantity of subsurface inflow from the older nonwater-bearing formations and from the underlying and flanking Paso Robles formation. Similarly, alluvium in Cholame Valley is replenished by stream percolation, percolation of rainfall, and excess irrigation water, as well as a minor amount of subsurface flow from adjacent nonwater-bearing rocks.

Recharge of the Paso Robles formation is rather complex. Percolation of rainfall and stream flow may occur directly on outcropping aquifers in areas of folding. In certain places in areas of folding where water levels are high, the aquifers discharge water to the surface. In some cases influent and effluent flow may occur on the same anticlinal structure within a hundred yards. Effluent flow occurs on the Huerhuero anticline in Huerhuero Creek; northeast of Bradley anticline in Vineyard Canyon and Indian Valley; and near the Paso Robles fault east of the Salinas River. Water percolates on the flanks of most folds. In the areas of flat lying sediments, vertical percolation is complex and devious as discussed above, and probably constitutes a major source of replenishment during wet periods. In the area north of Estrella Creek, northwest of Shandon, ephemeral springs caused by trapping of downward percolating waters by clays are common; however, successful irrigation wells are not known in this area. There are probably many areas of effluent flow not observed during this investigation which occur when water levels are high.

Ground water is withdrawn from the alluvium of the Salinas River by pumping, effluent flow, evapo-transpiration, subsurface flow into the lower Salinas Valley and possibly by a limited amount of subsurface flow into the Paso Robles formation. The location of areas of effluent flow in the Salinas River alluvium depend on the water level conditions. When the alluvium is full and the river stage is falling the entire length of the alluvium may be considered as having effluent flow. The areas of rising water during lowest water levels in September, 1953, were observed in the following locations: (1) between San Miguel and Wunpost, (2) between Eureka Bridge at Atascadero and a point some 300 yards upstream from the bridge, and (3) about half way between Templeton and Atascadero. The remainder of the river was dry at this time. Some of the rising water upstream from Wunpost probably comes from subsurface inflow from the Paso Robles formation. Alluvium in Cholame Valley is depleted by pumping, possibly by evapo-transpiration, and by subsurface outflow through alluvium and possibly through the San Andreas fault into the Paso Robles formation near Cholame.

Depletion of the Paso Robles formation occurs by pumping, evapo-transpiration, effluent flow, and subsurface outflow.

Ground Water Storage Capacity and Specific Yield. Ground water storage capacity below the water table of 1954 to the base of the Paso Robles formation is estimated to be extremely large; probably several millions of acre-feet. The average saturated depth is about 900 feet. Estimated ground water storage for the 100 feet of material below present water level is about 3,000,000 acre feet. This value is estimated to be in the correct order of magnitude for usable storage capacity, since pumping lifts would probably have to be 200 feet greater than present to utilize this amount of storage and still be within economical limits. Historical data on ground water levels are not available to determine actual historical changes in ground water storage, but they are believed to be small. Estimated weighted mean specific yield of the Paso Robles formation and alluvium is eight per cent. Storage capacity of the alluvium of the Salinas River is estimated to be only about 40,000 acre-feet, and specific yield is estimated to average 15 per cent.

Permeability, Subsurface Flow, and Yield of Wells. Permeability of the alluvium in the Salinas River near Atascadero and Paso Robles was found to be about 4,000 gallons per day per square foot from permeability pump tests. Permeability of the Paso Robles formation was found to vary from about 100 to 4,100 gallons per day per square foot, with an average value of about 200 gallons per day per square foot.

Subsurface flow from the Paso Robles Basin to the lower Salinas Valley has been estimated by the slope-area method. Subsurface outflow through the Paso Robles formation occurs east of the Salinas River and is estimated to be about 7,000 acre-feet per year. Water level control in this area is poor, however, and this estimate should not be considered to be too reliable. Subsurface outflow to the lower Salinas Valley also occurs through the alluvium and is estimated to be only about 150 acre-feet per year.

The Paso Robles formation yields up to 3,300 gpm to wells and the alluvium in the Salinas River yields up to 2,000 gpm to wells. Wells generally obtain water from unconsolidated sand and gravel, but one driller reports that the cemented beds of the Paso Robles formation also yield considerable water to wells.

Pozo Basin

The Pozo ground water basin is located upstream from Salinas Dam and includes a narrow strip of alluvium on the valley floor of the Salinas River and Pozo Creek. The alluvium ranges up to 30 feet in depth. It is replenished by percolation of stream flow, and by penetration of rainfall and return irrigation water. It is depleted by pumping, evapo-transpiration, and effluent flow. Total ground water storage capacity is estimated to be about 2,000 acre-feet. There were 17 irrigation wells in Pozo Basin in 1954. A maximum yield of 230 gallons per minute has been reported and the average yield for all wells is about 100 gallons per minute.

Ground Water Basins Within Coastal Unit

The Coastal Unit has been divided for descriptive purposes into three subunits, each of which includes several drainage areas. The three are the Cambria Subunit in the northern portion, the San Luis Obispo Subunit in the central portion, and the Arroyo Grande Subunit in the southern portion of the coast. The boundaries of the subunits and basins are shown on Plate 9B.

All coastal ground water basins in San Luis Obispo County have a similar late geologic history which is of considerable importance to occurrence of ground water. During the time prior to the last glacial period sea level was higher than at present and the coastal valleys were incised in essentially their present position, while the low terraces now found at 20 to 100 feet above sea level were being formed by wave erosion and deposition. During the last glacial period, sea level dropped to about 300 feet below its present level, and as the lowering occurred, the coastal valleys were incised. In some instances only narrow V-shaped canyons were formed and in others, where conditions were [illegible], wider valleys were eroded. At the time of [illegible] lowering of sea level the shore line was from two to eight miles from its present position and streams had this greater distance to flow to reach sea level. The stream valleys were incised in most places into nonwater-bearing rock, but in the Morro Bay and Arroyo Grande areas the streams cut into the older sand dunes and the Paso Robles formation. There is some evidence that harder rock has resisted erosion in some places, resulting in widening of the ancient valley upstream from the hard rock and steepening of the stream gradient below.

As the last glacial period declined and sea level rose, the streams dropped their material and backfilled the valleys. This alluvial backfill is the Recent and upper Pleistocene alluvium which is the principal aquifer of most of the coastal ground water basins.

Cambria Subunit

Principal ground water basins in the Cambria Subunit include San Carpoforo, Arroyo de la Cruz, San Simeon, Santa Rosa, Villa, Cayucos, Old, and Toro Basins. Pertinent geologic and hydrologic characteristics of these ground water basins, which correspond to the creeks of the same name, are included in Table B-5.

TABLE B-5

SUMMARY OF GROUND WATER BASIN CHARACTERISTICS
CAMBRIA SUBUNIT, COASTAL UNIT

	San Carpoforo Basin	Arroyo de la Cruz Basin	San Simeon Basin	Santa Rosa Basin	Villa Basin	Cayucos Basin	Old Basin	Toro Basin
Total surface area, in acres	200	750	620	2,360	980	980	750	490
Thickness of alluvium, in feet	0-60+	0-130+	0-100(?)	0-130+	0-130+	0-120(?)	0-135	0-80(?)
Depth of wells, in feet								
Maximum known	---	127	80	130	135	---	162	---
Estimated average	---	100	50	80	80	---	70	---
Depth of water, in feet								
Maximum	---	13	30	30	90	28	34	---
Minimum	---	0	5	6	5	4	8	8
Yield of irrigation wells, in gpm								
Maximum known	---	---	170	708	---	166	335	500
Estimated average	---	---	100	400	---	100	200	---
Specific capacity, in gpm/foot of drawdown								
Maximum known	---	---	---	50	---	14	24	---
Estimated average	---	---	---	15	---	10	15	---
Number of irrigation wells, 1954	0	5	6	9	3	2	3	1
Estimated average specific yield, in per cent	18	18	18	17	15	15	15	15
Estimated saturated storage capacity, in acre-feet	1,800	6,600	4,000	24,700	6,600	4,000	4,600	2,900
Estimated usable capacity, in acre-feet	600	2,200	1,300	6,000	2,200	1,300	1,500	1,000
Occurrence of ground water	Unconfined	Unconfined	Unconfined	Unconfined	Unconfined	Unconfined	Unconfined	Unconfined
Estimated maximum possible extent of sea-water intrusion, in miles from ocean	2	3	2	3	2.5	2	1.2	1

Geology. All of these ground water basins consist of alluvium of Recent and upper Pleistocene age which has been deposited as described above. In the Cambria Subunit the alluvium overlies nonwater-bearing rocks of Tertiary, Cretaceous and Jurassic age. Thickness of alluvium varies from 0 to over 130 feet in the ground water basins of the Cambria Subunit. As far as can be determined the alluvium is not disturbed by faulting or folding, and it apparently continues offshore and is in contact with sea water.

The base of the alluvial deposits on the terraces along the coast of this subunit is above sea level and therefore the alluvium contains little ground water, as it drains directly toward the ocean.

Ground Water. Ground water occurs in the alluvium and to a minor extent in fractures and slightly permeable zones in the older nonwater-bearing rocks. Ground water in alluvium is unconfined as far as is now known, although small clay caps may exist near the mouths of some of these ground water basins. Ground water moves downstream and essentially follows the slope of the ground surface. Ground water is replenished in these basins by percolation of stream flow and by deep penetration of precipitation and excess irrigation water. It appears that stream flow entering the ground water basins of the Cambria Subunit has been sufficient to essentially replenish the basins in nearly every year. Ground water is depleted by pumping, effluent flow, evapo-transpiration and subsurface flow into the ocean. The water table in most of these ground water basins is fairly close to the surface, and most of the trees and heavy brush in the basins probably obtain water from the water table. Rising water occurs for at least part of the year after the ground water basins are filled during the wet season. During the later part of the year when rising water occurs, the streams in many cases do not directly reach the ocean but are dammed by barrier beaches and sand dunes and water percolates to the ocean through the barriers. If the ground water basins were dewatered by pumping, sea-water intrusion would probably occur. However, intrusion cannot extend inland beyond the point where the base of the alluvium is at sea level elevation. This point of maximum intrusion is estimated for each basin in Table B-5.

Wells in the ground water basins of the Cambria Unit average about 80 feet in depth. Many of them completely penetrate the alluvium and have been drilled into nonwater-bearing rocks. Wells yield up to about 700 gallons per minute but average yield is probably on the order of 200 gallons per minute. Specific capacity of wells probably averages about 15 gallons per minute per foot of drawdown. As shown on Table B-5 the number of irrigation wells in each of these ground water basins is small.

San Luis Obispo Subunit

Ground water basins in the San Luis Obispo Subunit include Morro, Chorro, Los Osos, San Luis Obispo, and Pismo Basins corresponding to the name of the streams which traverse the ground water basins. The San Luis Obispo and Pismo ground water basins may be conveniently divided into upper and lower areas for descriptive purposes, the upper areas being located in the northwest-southeast trending San Luis Valley and the lower areas in the narrow north-south trending canyons. Pertinent geologic and hydrologic characteristics of these ground water basins are summarized in Table B-6.

TABLE B-6

SUMMARY OF GROUND WATER BASIN CHARACTERISTICS
SAN LUIS OBISPO SUBUNIT, COASTAL UNIT

	Morro Basin	Chorro Basin	Los Osos Basin	San Luis Obispo Basin	Pismo Basin
Total surface area, in acres	1,270	1,750	7,920	9,680	5,340
Thickness of alluvium, in feet	0-130	0-80	0-100(?)	0-100(?)	0-100(?)
Thickness of old sand dunes, in feet	---	---	0-150	---	---
Thickness of Paso Robles formation, in feet	---	---	0-?	0-160	0-360
Depth of wells, in feet					
Maximum known	90	150	212	210	110
Estimated average	80	70	60	90	60
Depth to water, in feet					
Maximum	52	23	83	30	42
Minimum	4	2	2	2	0
Yield of irrigation wells, in gpm					
Maximum known	442	700	396	600	200
Estimated average	300	200	200	500	---
Specific capacity, in gpm/foot of drawdown					
Maximum known	73	29	95	20	---
Estimated average	30	15	15	15	---
Number of irrigation wells, 1954	12	4	13	29	15
Estimated average specific yield of all sediments, in per cent	.12	.12	.20	.13	.12
Estimated saturated storage capacity, in acre-feet	7,600	9,600	95,000+	67,000	30,000
Estimated usable capacity, in acre-feet	2,000	2,500	9,000	22,000	10,000
Occurrence of ground water	Unconfined	Unconfined	Unconfined	Unconfined and confined	Confined and unconfined
Estimated maximum possible extent of sea-water intrusion, in miles from ocean	1.3	1.5	---	1	1

Geology. The Morro and Chorro ground water basins are similar to those described in the Cambria Subunit in that they consist of Recent and upper Pleistocene alluvium overlying nonwater-bearing rock. The marine terrace deposits extending from Morro Creek north to one-third mile south of Toro Creek lie partly below sea level. They are at least 60 feet deep as the drillers log of one well indicates.

Geology of the Los Osos, San Luis Obispo, and Pismo basins is more complicated than the basins to the north in that water-bearing sediments consist of Recent and upper Pleistocene alluvium, sand dunes and terrace deposits of upper Pleistocene age, as well as the Paso Robles formation of Plio-Pleistocene age. The Paso Robles formation consists of lenticular sand, gravel, and clay, with very poor bedding. The Paso Robles was deposited in the northwest-southeast trending San Luis Valley, and probably in Los Osos Valley and Morro Bay. The presence of materials which may be of the Paso Robles formation is indicated by drillers logs of wells near Morro Bay, but no outcrops were identified there during the field investigation. The Paso Robles formation does outcrop in the upper main portion of both the San Luis Obispo and Pismo Creek Basins where it has been gently folded into a syncline (see Geologic Map, Plate 7B), and has a maximum known thickness of 160 feet. The Pismo and San Luis Obispo Basins are arbitrarily separated in the area of outcrop of the Paso Robles formation at the drainage divide, although the ground water divide does not appear to correspond with the drainage divide (see Plate 9B).

In the San Luis Obispo Subunit older sand dunes are found only in the Los Osos Basin and at the town of Morro Bay as shown on Geologic Cross Sections E-E' and F-F', Plate 8B, and on the Geologic Map, Plate 7B. The older sand dunes are up to 150 feet thick and extend to and slightly below sea level.

The older sand dunes are weathered to a brown or reddish color and are fine grained as is usually the case with wind blown sand deposits. Water well logs indicate that occasional clay lenses are found in the sand dunes. Some terrace deposits up to about 100 feet thick in the San Luis Obispo Basin near Laguna Lake are probably the age equivalent of the older sand dunes.

Alluvium, which reaches a maximum thickness of about 100 feet, occupies the valley floor of all the ground water basins and is the principal aquifer. Large areas in the San Luis Obispo and Pismo Basins where the alluvium has a thickness of less than 10 feet and exposures of bedrock are common are not included on the geologic map since the alluvium does not yield much water to wells or is above the water table. The younger sand dunes in the Morro Bay area contain ground water but are not extensive enough to be of hydrologic significance.

Ground Water. Ground water occurs in alluvium, older sand dunes, and in the Paso Robles formation and is unconfined in most portions of the basins. The only flowing wells noted in this subunit were in the alluvium of the broad upper part of San Luis Obispo and Pismo Basins just upstream from the narrow canyons mentioned above, indicating that conditions of at least partial confinement exist in those areas. Bedrock is exposed in a part of the narrow canyon of Pismo Creek and is a natural dividing area between the large upper portion and the small lower portion of the Pismo Ground Water Basin.

Ground water generally moves in the direction of surface slope except in Los Osos Basin, where it moves in a northerly direction in the older sand dunes as shown by water level contours on Plate 9B. Ground water is replenished by percolation of stream flow, precipitation and return irrigation water, as well as by minor amounts of subsurface inflow from older rocks. Ground water is depleted by pumping, evapo-transpiration, effluent flow, and subsurface flow to the ocean. In general the best wells are located in the alluvium. The yield of wells in the dune sand is limited by sand coming into wells. The older sand dunes, however, yield soft water of excellent quality. The yield of wells in the Paso Robles formation is fair but generally less than wells in alluvium. Many stock and domestic wells obtain limited supplies from fractured older rocks.

Since alluvium is in contact with sea water it is reasonable to expect that sea-water intrusion could occur if landward gradients are established by heavy pumping in the future. As far as is known, however, no landward gradient has existed except in cones of depression near pumping wells for a short period of time, and sea-water intrusion has probably not occurred up to 1955.

Arroyo Grande Subunit

Ground water basins in the Arroyo Grande Subunit include the Arroyo Grande Basin and Nipomo Mesa. Pertinent geologic and hydrologic characteristics are summarized in Table B-7.

TABLE B-7

SUMMARY OF GROUND WATER BASIN CHARACTERISTICS
ARROYO GRANDE SUBUNIT, COASTAL UNIT

	Arroyo Grande	Nipomo Mesa
Total surface area, in acres	12,460	16,020
Thickness of alluvium, in feet	0-200±	----
Thickness of old sand dunes, in feet	0-100	0-300
Thickness of Paso Robles formation, in feet	0-200	0-900
Depth of wells, in feet		
Maximum known	252	810
Extimated average	100	400
Depth of water, in feet		
Maximum	93	237
Minimum	0	5
Yield of irrigation wells, in gpm		
Maximum known	1,200	1,500
Estimated average	360	100
Specific capacity, in gpm/foot of drawdown		
Maximum known	500	29
Estimated average	40	5
Number of irrigation wells, 1954	123	6
Estimated average specific yield, in per cent	15	18
Estimated saturated storage capacity, in acre-feet	226,000	770,000+
Estimated usuable capacity, in acre-feet	40,000	?
Occurrence of ground water	Confined and unconfined	Unconfined

Geology. Areal geology of the Arroyo Grande Basin and Nipomo Mesa is shown on the geologic map (Plate 7B) and on geologic cross-sections G-G', H-H', and J-J' on Plate 8B. Water-bearing formations include alluvium, older sand dunes, and the Paso Robles formation. In addition, the Careaga sand is found beneath the Paso Robles formation in the Nipomo Mesa area, but does not outcrop in San Luis Obispo County. The Careaga sand is a marine, medium-grained sand of Plio-Pleistocene age. It attains a thickness of 650 feet in the Santa Maria basin, but thins to a feather edge under the Nipomo Mesa as shown on cross-sections H-H' and J-J'.

The Paso Robles formation consists of sand, gravel, and clay up to 900 feet thick in Nipomo Mesa, up to 200 feet thick in the lower part of the Arroyo Grande basin, and up to 2,000 feet thick in the Santa Maria Valley in Santa Barbara County. The Paso Robles formation thins to the north and west from the vicinity of Oso Flaco Lake. Both the Careaga sand and Paso Robles formation in San Luis Obispo County form the north flank of a syncline whose axis is located along the south edge of the Santa Maria Valley (Worts and Thomasson, 1951, and Woodring and Bramlette, 1950). At the mouth of the valley of Los Berros Creek the Paso Robles formation has been folded and has a dip of 15 degrees to the southeast, but in most places the Paso Robles has a dip of less than five degrees.

After deposition of the Paso Robles formation, sand dunes up to 300 feet thick were deposited on Nipomo Mesa and up to 100 feet of sand dunes were deposited in the area north and east of Oceano. These dune sands have since been tilted, partially eroded away, and weathered, and they are called the older sand dunes in this report. Worts and Thomasson (1951) mapped a stream deposited gravel bed in the southeast part of the Nipomo Mesa and called it the Orcutt formation, but it is included with the older sand dunes in this report since the mapped bed is thin on the outcrop and cannot be identified in logs of wells drilled in Nipomo Mesa.

All of these older formations were eroded by Arroyo Grande Creek and the Santa Maria River during the last glacial stage when sea level was about 300 feet lower than at present. As the glacial period waned and sea level rose, the sediment loads of Arroyo Grande Creek and the Santa Maria River were deposited, forming the alluvium of Recent and upper Pleistocene age. Alluvium in Arroyo Grande Creek is about 100 feet thick in the valley upstream from the town of Arroyo Grande, and possibly 200 feet thick near the present shore line. Available well logs confirm the presence of a fine-grained upper member of the alluvium in Arroyo Grande Basin near the coast. This upper member acts as a confining bed to ground water and wells flow when the piezometric surface is above the ground surface.

The sand dunes of Recent age along the coast are generally less than 50 feet thick but reach a maximum thickness of 100 feet. They overlie alluvium and older sand dunes. The alluvium of Arroyo Grande Valley has probably not been folded or faulted. The older sand dunes have apparently been tilted to the southwest to some extent so that the base of the sand dunes is now below sea level (see cross-section J-J', Plate 8B). The Paso Robles formation is concealed by sand dunes in most areas, but oil well logs and available outcrops indicate that it dips to the southwest and toward the Santa Maria Valley.

<u>Ground Water</u>. Ground water occurs in alluvium, older sand dunes, the Paso Robles formation, and the Careaga sand. The principal aquifer of the Arroyo Grande Basin is alluvium, but many wells obtain water from the Paso Robles formation underlying the older sand dunes in the area between Oceano and Arroyo Grande, and a few wells obtain water from the Paso Robles formation in the Los Berros Creek area. Nonwater-bearing rocks underlie the water-bearing

sediments, but some wells obtain limited quantities from these rocks and one well, drilled into Miocene rocks, yields about 500 gallons per minute.

Ground water in the older sand dunes is generally low in total dissolved solids and hardness since it is derived mostly from percolation of precipitation. Ground water in older formations is generally higher in total dissolved solids and hardness.

Ground water movement is indicated by contours on Plate 9B. Of considerable interest is the fact that ground water moves from Nipomo Mesa toward Los Berros Creek, Arroyo Grande Valley, the ocean, and toward Santa Maria Valley. It is probable that movement in the reverse direction will occur if future increased pumping on Nipomo Mesa exceeds natural recharge. Ground water in Arroyo Grande Basin generally moves downstream except where temporary cones of depression are formed near pumping wells. In the area north of Oceano, pumping has formed a large depression in the water table, the deepest part having been below sea level most of the time during the 1945 to 1955 period. Oceanward of this large depression, however, water levels are above sea level, indicating that sea-water intrusion probably is not occurring. The large depression is apparently caused by the reduced permeability of the Paso Robles formation and fairly heavy draft requiring a steeper hydraulic gradient to transmit the water to the wells in the area. The sediments underlying the older sand dunes in the area of the depression contain fairly extensive clay lenses which cause local pressure effects. Near the ocean west of the depression the clays apparently are not very extensive, and ground water in the older sand dunes probably percolates downward into the Paso Robles formation and maintains a seaward hydraulic gradient. Just north of Nipomo Mesa ground water in the alluvium moves in a northwesterly direction and is confined by a clay cap.

Ground water in Arroyo Grande Basin is replenished by percolation of stream flow, rainfall, and excess irrigation water as well as by subsurface flow from Nipomo Mesa. Most of the area of Nipomo Mesa is internally drained. The old sand dunes underlying the mesa have large closed depressions and the sand has a sufficiently high percolation rate to absorb all rainfall not consumptively used or evaporated. Flow from springs in Black Lake Canyon drains to the Recent sand dunes, but there the water percolates into the sand dunes and moves underground to the ocean. No streams drain into, out of, or across Nipomo Mesa, and therefore the major source of replenishment of ground water is percolation of precipitation. That this replenishment has occurred in the past is evidenced by the fact that the basin is so full that ground water now moves out of the area toward the adjacent ground basins and the ocean. An additional source of supply may consist of a small amount of subsurface inflow which has percolated from the alluvium of Nipomo Creek on the east. Under conditions of heavy draft sea-water intrusion may occur.

Ground water is depleted in Arroyo Grande Basin and Nipomo Mesa by pumping, subsurface outflow, and evapo-transpiration. Ground water is exported from the Oceano area of Arroyo Grande Basin to Pismo Beach.

The effluent water which reaches a maximum amount of flow at the U. S. Geological Survey gage at Arroyo Grande is probably caused by the decrease of cross-sectional area of alluvium. When water levels are further drawn down by pumping, the effluent flow at the gage will stop. Most of the effluent water percolates below Arroyo Grande during the irrigation season. Water which does not percolate flows to and over the clay cap and is wasted to the ocean.

Wells in Arroyo Grande Basin generally obtain most yield where drilled into alluvium. The Paso Robles formation north and east of Oceano and in the Los Berros Creek area generally yields less water to wells. Wells in the sand dunes do not yield much water because of inflow of sand during high pumping rates. Yields of wells, specific capacities, storage capacities and other hydrologic factors are summarized in Table B-7.

Carrizo Plain Unit

The Carrizo Plain Unit consists primarily of the Carrizo Plain, but Elkhorn Plain and a few other internally drained areas in the extreme southeast portion of San Luis Obispo County and in adjacent Kern County are also included. Carrizo Plain is the largest area of internal drainage in the Coast Ranges. The internal drainage has been preserved primarily because of low rainfall and relatively small tributary mountain areas, resulting in limited runoff. Excess runoff evaporates in Soda Lake in the central portion of the plain. A review of historical records indicates that standing water in Soda Lake has been noted only during the wet months and in summers following very heavy spring rains. Pertinent physical features of the Carrizo Plain Basin are summarized in Table B-8.

TABLE B-8

SUMMARY OF GROUND WATER BASIN CHARACTERISTICS
CARRIZO PLAIN UNIT

Total surface area, in acres	172,000
Thickness of alluvium, in feet	0 - 100'
Thickness of Paso Robles formation, in feet	0 - 1,000'
Depth of wells, in feet	
Maximum known	600
Estimated average	200
Depth to water, in feet	
Maximum	58
Minimum	12
Yield of irrigation wells, in gpm	
Maximum known	1,100
Estimated average	500
Specific capacity, in gpm/foot of drawdown	
Maximum known	15
Estimated average	5
Number of irrigation wells, 1954	8
Occurrence of ground water	Unconfined and confined

Geology

Geologic features of the Carrizo Plain Unit are shown on Plate 7C. Water-bearing materials include alluvium and the Paso Robles formation. The Paso Robles formation (also called the Tulare formation in this area by some workers) consists of more than 1,000 feet of clay, sand, and gravel. Drillers logs and electric logs of oil wells indicate that the Paso Robles formation underlying the alluvium is moderately high in clay content in the north part of the unit and very high in clay and silt near and south of Soda Lake. Surface outcrops indicate the same general gradation of sediments in a southerly direction although outcrops are poor. In general the thickest portion of the Paso Robles formation is found on the north and west sides of the Carrizo Plain Unit. This probably has been the result of down folding or faulting of the area near the San Andreas fault and up folding or faulting of the western side of the Carrizo Plain and the Caliente Mountains.

Alluvium is probably only 100 feet or less in thickness, although well log data are scant. Alluvium on the surface consists of relatively coarse alluvial fan sediments around the periphery of the Carrizo Plain and Elkhorn Plain and fine-grained lake deposits near the central parts of those areas. During a previous wet cycle, possible during the last glacial age, Soda Lake was considerably more extensive than at present as shown by poorly preserved, eroded terraces and by extensive salt deposits in the soil. Aerial photographs show this ancient shore line reasonably well by changes in vegetation and in soil color. The shore line coincides only poorly with the present surface contours, probably indicating that the shore line has been altered by recent tectonic activity. Deposition of alluvium is affected by the San Andreas fault and some streams have been off set by faulting. The Paso Robles formation has been both faulted and folded.

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