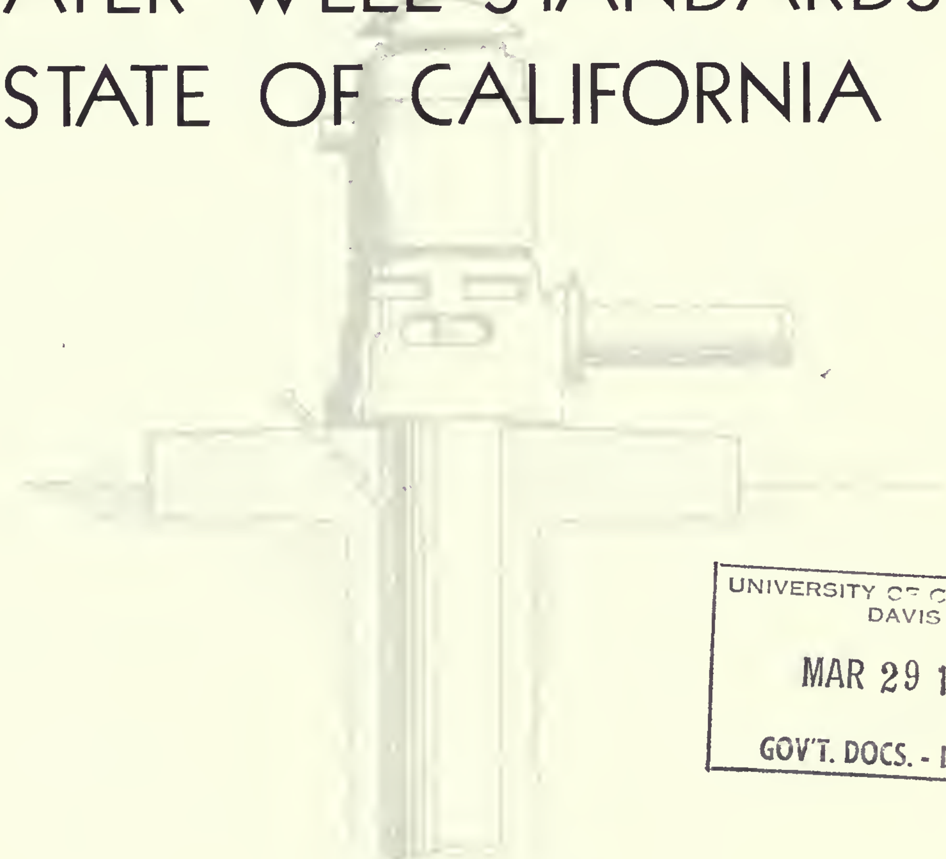
STATE OF CALIFORNIA
The Resources Agency

Department of Water Resources

BULLETIN No. 74

WATER WELL STANDARDS: STATE OF CALIFORNIA



FEBRUARY 1968

RONALD REAGAN
Governor
State of California

WILLIAM R. GIANELLI
Director
Department of Water Resources

ERRATA SHEET

to

Bulletin No. 74, "Water Well Standards: State of California"

Please note the following corrections:

1. Page 23:

   Fourth line from the top, the word well should read wall.

2. Page 64:

   Second paragraph, last line, Appendix D should read Appendix C.

3. Page 114:

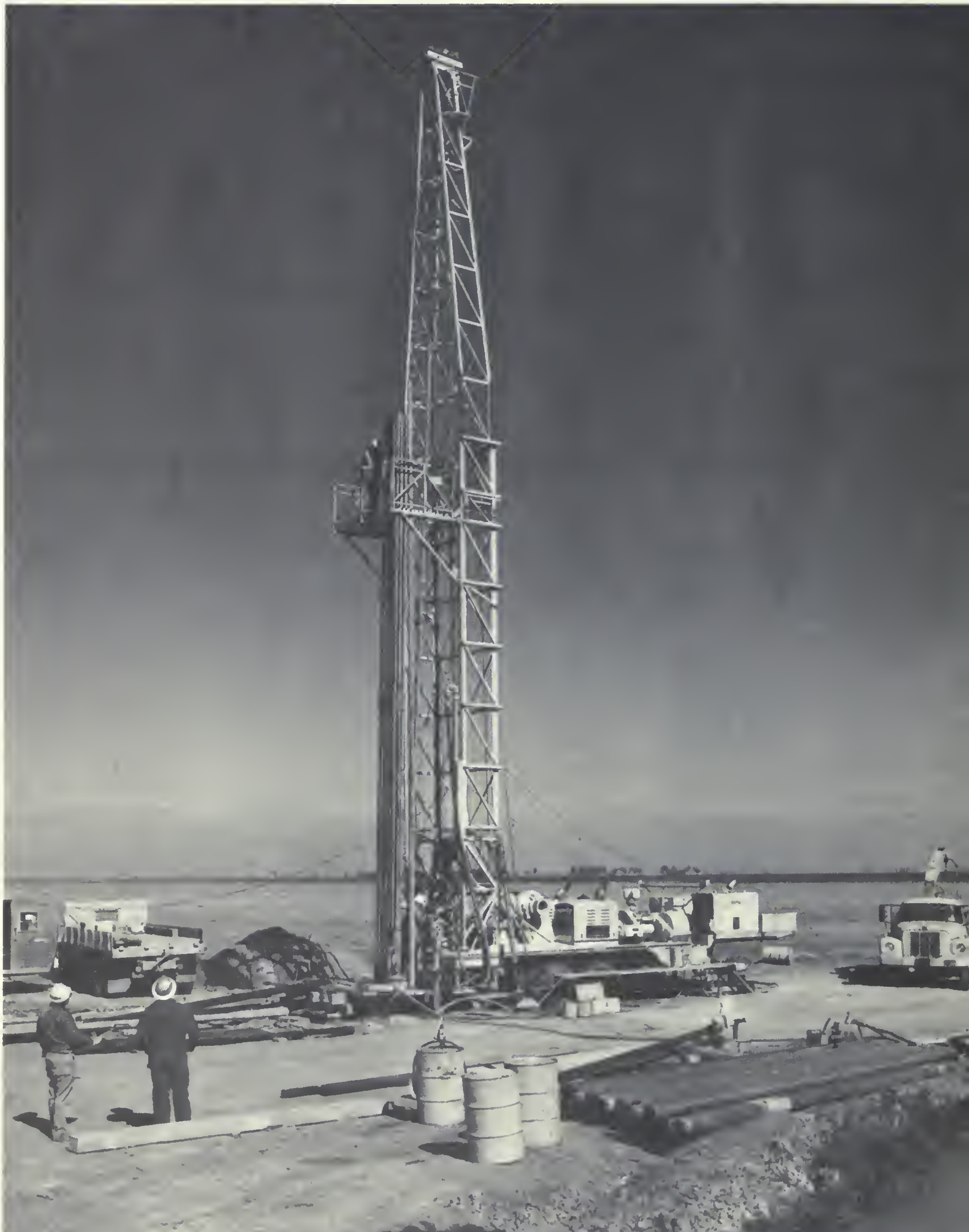
   Table 4, the fourth item, Other should be indented under Sewer Lines.

4. Page 126:

   Fourth line from the top, the word unconsolidated should read consolidated.

5. Page 157:

   Last paragraph, first line, the word exercised should read exercises.



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FEBRUARY 1968

RONALD REAGAN
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WILLIAM R. GIANELLI
Director
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FOREWORD

The standards presented in this report are issued as guides to good practice for those engaged in the construction of water wells or in the regulation of water well construction and the destruction of abandoned wells in California. They fulfill the need for a basic set of standards that are satisfactory under most conditions and which can be modified or expanded to accommodate local variations in geologic or ground water conditions. As work is completed, the Department of Water Resources will issue its recommendations for supplemental or different standards for use in various areas in the State. The Department recommends that counties and cities which have not already done so give consideration to enacting water well construction ordinances to protect the quality of ground water supplies in their areas.

Whereas the standards presented in this report are as final as they can be at the present time, the Department will revise them from time to time. We recognize that, as with other published standards, to be effective and useful they must be revised and updated in light of both changes in practice and the degree of success achieved in their application.

William R. Gianelli

William R. Gianelli, Director
Department of Water Resources
The Resources Agency
State of California
December 16, 1967

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STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

RONALD REAGAN, Governor
WILLIAM R. GIANELLI, Director of Water Resources
JOHN R. TEERINK, Deputy Director

STATEWIDE PLANNING OFFICE

John M. Haley	Chief
Charles F. Kleine	Chief, Data Coordination Branch

This report was prepared
By

Edwin A. Ritchie	Associate Engineer, Water Resources

Assisted by

Mrs. Margaret M. Reterink	Intermediate Typist

-----0-----

Appendix D was prepared by

James M. Carl	Senior Attorney

-----0-----

The portions of this report pertaining to community water supply wells were prepared in cooperation with Clarence L. Young, Senior Sanitary Engineer, California Department of Public Health, Bureau of Sanitary Engineering.

CALIFORNIA WATER COMMISSION

IRA J. CHRISMAN, Chairman, Visalia

WILLIAM H. JENNINGS, Vice Chairman, La Mesa

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EDWIN KOSTER, Grass Valley

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MARION R. WALKER, Ventura

-----0-----

WILLIAM M. CARAH
Executive Secretary

WILLIAM L. BERRY, SR.
Engineer

ACKNOWLEDGMENT

We are grateful for the cooperation provided by agencies of the Federal Government, State of California, counties, cities, professional organizations, businesses and many individual water well drillers.

Special recognition is made of the following organizations:

State Department of Public Health, Bureau of Sanitary Engineering

Associated Drilling Contractors of California, its Board of Directors and Specifications Committee

The Department wishes also to acknowledge its appreciation to all of those who submitted comments on the preliminary and interim editions.

AUTHORIZATION

The Water Well Standards Program under which this report was prepared is authorized by Section 231 of the Water Code, State of California which reads:

> "231. The department, either independently or in cooperation with any person or any county, state, federal or other agency, shall investigate and survey conditions of damage to quality of underground waters, which conditions are or may be caused by improperly constructed, abandoned or defective wells through the interconnection of strata or the introduction of surface waters into underground waters. The department shall report to the appropriate regional water quality control board its recommendations for minimum standards of well construction in any particular locality in which it deems regulation necessary to protection of quality of underground water, and shall report to the Legislature from time to time, its recommendations for proper sealing of abandoned wells."

ABSTRACT

About one half of the fresh water used in California is obtained from underground. There are some 500,000 water wells scattered throughout California. Each year about 10,000 wells are constructed or rehabilitated, and numerous wells are abandoned. / If not properly constructed or if inadequately destroyed, a well may contribute to the impairment of the quality of ground water in the area. A properly constructed or adequately destroyed well should maintain the subsurface conditions that existed before the well was constructed. / Chapter 1522, Statutes of 1949, now Section 231 of the Water Code of the State of California, directs the Department of Water Resources to formulate recommendations for standards of water well construction and sealing. Standards for the construction of water wells and for the destruction of abandoned wells can be a significant factor in the protection of ground water quality. / The State Department of Public Health has a concurrent interest in these standards. The Department of Public Health must determine that all water intended for public use will not endanger the health or life of the user. / / The responsibility of the Department of Water Resources is to advise the Legislature and appropriate State agencies on the maintenance of good quality water as it occurs in underground formations, including protection against adverse effects caused by improper well construction or abandonment. This responsibility applies to all wells regardless of purpose.

CHAPTER I. INTRODUCTION

Approximately one-half of the 33.6 million acre-feet of fresh water used in California in 1965 came from underground. These waters were obtained primarily from wells. It is estimated that there are roughly 500,000 water wells (irrespective of condition or whether used or idle) scattered throughout the State. Most are situated in the more than 250 larger ground water basins in California. They range from the hand dug wells more familiar in years past to carefully designed large production wells drilled hundreds and even thousands of feet.

Currently, around 10,000 water wells are constructed or rehabilitated each year throughout the State, and numerous wells are "abandoned". If these wells are not properly constructed initially, or are not satisfactorily reconstructed when defective, or if they are inadequately destroyed when they no longer serve a useful purpose, they may permit impairment of the quality of ground waters detrimental to one or several intended uses. A properly constructed or adequately destroyed well should maintain, as far as practicable, those subsurface conditions which existed prior to construction of the well and which prevented the entrance of waters of unsanitary and inferior mineral quality into usable ground water supplies.

If we are to develop ground water supplies to their maximum capability, including use in conjunction with surface water to provide for California's needs, we are obligated to protect their quality for this and future generations. Standards for the construction of water wells and for the destruction of so-called "abandoned" wells can be a significant factor in the protection of ground water quality and should contribute to the betterment of the health and welfare of the people of the State.

Impairment of the quality of ground waters of the State through improper construction or abandonment of wells is only one aspect of the water pollution problem in California. Concern over water pollution caused the Legislature to conduct extensive public hearings on the problem during the late 1940's. Subsequently, a number of water pollution control acts were adopted. Among these was legislation directing the Department of Water Resources to formulate recommendations for standards of water well construction and sealing. This legislation was enacted as Chapter 1552, Statutes of 1949, now Section 231 of the Water Code, State of California.

During, and in the period between the 1965 and 1967 General Sessions, the Legislature reviewed the matter of standards for water well construction once more. As a result, they established a procedure for implementing standards developed under Section 231 by enacting Chapter 323, Statutes of 1967, which added Sections 13800 through 13806 to the Water Code. In Section 13800, the Department of Water Resources' reporting responsibility is enlarged upon:

> "13800. The department, after such studies and investigations pursuant to Section 231 as it finds necessary, on determining that water well construction, maintenance, abandonment, and destruction standards are needed in an area to protect the quality of water used or which may be used for any beneficial use, shall so report to the appropriate regional water quality control board and to the State Department of Public Health. The report shall contain such recommended standards for water well construction, maintenance, abandonment, and destruction as, in the department's opinion, are necessary to protect the quality of any affected water."

In addition to the Department of Water Resources, the State Department of Public Health has a concurrent interest in problems caused by improperly constructed, defective, or "abandoned" wells. This interest is evidenced in the "Pure Water Act" (Chapter 7 of Part 1 of Division 5 of the Health and Safety Code, State of California, added by Chapter 992, Statutes of 1947), which deals with the health aspects of public water supplies. Under this authorization, the State Board of Public Health, in granting permits to water purveyors for supplying water for domestic (public) purposes, must find that under all circumstances it is pure, wholesome, and potable and does not endanger the lives or health of human beings. Further, the State Board of Public Health may adopt rules and regulations for the State Department of Public Health to use in the execution of its duties. Proposed well construction standards have been drafted by the Department of Public Health but their standards have not been formally adopted as regulations.

In broad terms, the responsibility of the Department of Water Resources is to advise the Legislature and the appropriate state agencies with regard to the maintenance of the quality of water as it occurs in underground formations, including protection against adverse effects caused by improper well construction or abandonment. This responsibility applies to all wells irrespective of purpose. The responsibility of the State Department of Public Health is to investigate, evaluate, and approve water supplies serving the public. When approving supplies utilizing well sources, consideration is given to the design and construction of the wells in order to preclude contamination by upper formation water or sewage hazards which may exist or develop in the future.

This report was prepared as part of a continuing program of the Department of Water Resources for discharging its responsibilities under the provisions of Section 231 of the Water Code, and in cooperation with the State Department of Public Health.

Statement of the Problem

Wells per se do not cause ground water quality impairment. Rather, inadequacies in their construction, or their improper destruction when they no longer serve a useful purpose, may result in the deterioration of the quality of ground water. The deterioration in quality, depending on various conditions, may be local and confined to the water supplying a single well, or may be more extensive, as in the instance of sea water intrusion, perhaps effecting a sizable segment of a ground water basin.

While the latter condition is more encompassing, the deterioration of the quality of water supplying an individual well, or groups of closely adjacent wells, is the most common and the most significant from the standpoint of public health. Underground sources of supply have been responsible for a sizable portion of the outbreaks of the water-borne diseases reported in the United States. Most of these outbreaks occurred where shallow wells were so poorly constructed that they allowed contaminants to enter the well. The contaminants entering improperly constructed wells are not limited to disease organisms or, for that matter, are not related to health problems alone. Literature on the subject is replete with examples of undesirable chemicals, both toxic and nontoxic, which gained access to the ground water, with the results that water in wells a short distance away was adversely affected.

The mechanism of water quality impairment caused by faulty wells in larger portions of a ground water basin or in an entire basin is not so well defined. In those instances where the quality of water in a segment of ground water basin has been impaired, a number of factors have been involved, and the wells served primarily to facilitate the impairment. The most noteworthy examples in California of deterioration of water quality in a sizable portion of a ground water basin are those coastal ground water basins which have been intruded by that massive source of degradation -- the ocean.

So far as is known, inadequately constructed or improperly "abandoned" wells have not yet been found to be sole cause of water quality degradation, where a sizable portion of California ground water basin has been involved. Nevertheless, even a small quantity of certain contaminants or pollutants entering a well may have far-reaching effects. In any event, the construction of thousands of additional wells in California each year, coupled with the fact that many of them are becoming more closely spaced, and an increase in the number of wells which can be expected to fall into a state of disrepair or indiscriminately abandoned, indicate that the potential for impairing the quality of segments of, or even entire, basins continues to grow. Then, when actual movement of the degrading substance along the lines of natural water movement occurs, the effects are generally long-lasting and difficult, if not impossible, to remedy owing to the extremely slow movement of ground water.

There are four principal ways in which inadequately constructed or improperly abandoned wells facilitate the impairment of ground water quality. These are:

1. When the surface portion of the well is constructed without protective features so that if it is overtopped by contaminated or polluted waters, they are permitted to flow directly into the well through one or more of several possible openings. Under these circumstances, only the water within or adjacent to the well is usually affected.

2. When the annular space, that is, the space between the outside of the casing and the wall of the hole, lacks an adequate vertical seal and undesirable surface or shallow, subsurface water flows laterally into the well along the outside of the casing. This type of defective well is particularly hazardous.

3. When, during well construction (or destruction), aquifers that produce water of undesirable quality are ineffectively sealed off such that interchange of water, if allowed to take place, will result in a significant deterioration of the quality of water in one or more other aquifers. The well now provides a physical connection between aquifers.

4. When the well is used intentionally, accidentally, or carelessly for the disposal of waste. Such disposal may or may not be operating under requirements prescribed by law.

Irrespective of the probability of occurrence and which form of deterioration takes place, California's ground water supplies must be preserved and protected to meet the increasing demands which are being made on them. Moreover, while the well construction industry, advisory groups, and regulatory agencies obviously intend to prevent any impairment of the quality of the State's ground water supplies which might result from improperly constructed or "abandoned wells, there appears to be no broad, uniform approach to the development of the means of such prevention in California. It follows then that the resolution of this dilemma requires the development of standards for water well construction and destruction, which will, if followed, assure the protection of the quality of the State's ground waters as they exist in the ground or as they pass through the well for use. In addition to providing for the protection of the quality of ground water, these standards should be capable of execution by the average competent well driller using commercially available equipment and materials, without imposing undue financial burden on the owner of the well or the driller.

Scope of Program and Report

The purpose of the Department of Water Resources' Water Well Standards program is to formulate recommendations for minimum standards to protect the quality of the State's ground water resources from impairment that might result from inadequately constructed, defective, or improperly abandoned wells. It is further intended that these standards be met with the construction methods commonly employed in California and at reasonable cost.

It was almost immediately apparent at the start of the program that many standards could, in general, be applied practically anywhere in the State. As an example, locating a house well a short distance from a septic tank is as bad as practice in Del Norte County, at the northwest corner of California, as it is in San Diego County. Similarly, sealing off waters from one or more zones or aquifers, so as to prevent their migration to other zones or aquivers, may be just as desirable at Merced as it is at Oxnard, although it may not be necessary at Merced as is the case at Oxnard. The above examples illustrate the importance of the proper application of standards.

Consequently, the program was divided into two activities: (1) studies leading to the formulation of Statewide Standards and (2) studies of various subareas of the State where it is felt that supplemental standards are needed and desirable. The general statewide standards form a basis on which supplemental or more stringent and specific standards can be developed for application in particular areas in the State.

Recommended statewide standards for water well construction and sealing were first presented in the preliminary edition of this bulletin issued in 1962.* Investigations have been made, and are being conducted in certain areas of the State, to formulate standards for water well construction similar to those in this report, but designed specifically for these localities. In the future, these local or area standards will be based on the general statewide standards presented herein, modified and augmented in accordance with local conditions. The status of reports for areas of study in various parts of the State is summarized in the following table:

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* Titled "Recommended Minimum Well Construction and Sealing Standards for Protection of Ground Water Quality State of California", Preliminary Edition, July 1962.

STATUS OF REPORTS
UNDER WATER WELL STANDARDS PROGRAM

Area of Study	Department of Water Resources Bulletin Number	Status
Mendocino County	62	Published November 1958
West Coast Basin (Los Angeles County)	107	Published August 1962
Alameda County	74-2	Published June 1964
Del Norte County	74-3	Published August 1966
Central, Hollywood and Santa Monica Basins (Los Angeles County)	74-4	Preliminary Edition October 1965 Final Edition, 1968
San Joaquin County	74-5	Preliminary Edition May 1965 Final Edition Scheduled June 1968
Fresno County	74-6	Preliminary Edition Scheduled June 1968
Shasta County	74-8	Preliminary Edition Scheduled June 1968
Ventura County	74-9	Preliminary Edition drafted. To be printed 1968

During the studies leading to this publication, information relating to various factors which might influence well standards were compiled and evaluated. For the purposes of this report, these factors have been grouped into the following broad categories: (1) ground water geology and hydrology (2) impairment to ground water quality and (3) water well construction practices including laws and regulations pertaining to ground water and water wells.

Numerous publications related to construction of water wells and to development, use, and protection of ground waters have been reviewd in preparation of this report. They are listed in Appendix J in alphabetical order by author.

Many technical terms concerning ground water and water well construction are frequently misunderstood and misinterpreted. The term "seal" or "sealing" for example has several meanings in the jargon of the well driller, geologist, and engineer, depending on what part of the well installation is under discussion. Every effort has been made in this report to insure that the technical terms used are understandable. A list of definitions is presented in Appendix I. Certain definitions are made a part of the standards presented in Chapter II.

Studies leading to the development of statewide standards for construction of water wells and for sealing of abandoned wells began in 1952 with a comprehensive survey of existing laws and regulations governing well construction and abandonment in the then 47 other states and in the counties and cities of California. This survey culminated in the publication of "Water Quality Investigations Report No. 9 - Abstracts of Laws and Recommendations Concerning Water Well Construction and Sealing in the United States", April 1955 (24)*. Report No. 9 contains, in addition to the standards

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* Reference to publication in Appendix J.

of the various aforementioned political subdivisions, standards promulgated by other public agencies and private organizations. Although the information in the report is over 10 years old, it still remains useful. The Department has continued to keep informed of practices in other states, particularly those in which standards have been established or are under active consideration.

Information relating to the occurrence and nature of ground water in California was obtained from reports prepared by the Department (and its predecessors), as well as from reports of other agencies. The information was reviewed with particular attention to conditions which relate to the construction of water wells or the closure of "abandoned" wells.

Similarly, information regarding ground water quality and its impairment was gathered from departmental or other agency studies and publications. Specific cases involving quality deterioration were reviewed.

Information, suggestions, and recommendations regarding methods and materials used were obtained from correspondence and interviews with representatives of state and federal agencies, steel companies, casing fabricators, pump manufacturers, water well drilling contractors, and other organizations and individuals associated with the development and use of ground water supplies. Included in these are replies to inquiries sent, in 1956, to the 766 water well drillers known to be operating in the State at that time. A 35 percent response was received. In addition, logs of water wells submitted by well drillers have from time to time been reviewed.

Legislation in California was reviewed concerning the powers and limitations that govern state and local agencies with respect to regulation of the construction and destruction of water wells. In November 1958, municipalities in California were polled again to update information obtained in 1952[24] regarding local regulation. Since publication of the preliminary edition of this report in 1962, the Department has kept informed of changes in the status of California county ordinances pertaining to well construction.

Public Hearings on the Preliminary Edition

In the Preface to the preliminary edition of this bulletin, the Department stated that:

> "After sufficient time has elapsed so that interested state and local agencies and members of the water well drilling industry may consider and comment upon the recommended standards presented in this report, the Department of Water Resources will conduct hearings prior to issuing these standards in final form. This procedure should take approximately two years...."

The edition was distributed in December 1962; in March and April 1965, a series of hearings was held in conjunction with the Department of Public Health at six cities in the State. Discussion at each meeting centered around two major areas: (1) the standards recommended and (2) means of implementation. Written comments were also received.

The number of comments and questions on application of the standards, under various conditions, to differing uses of wells, and to different areas within the State demonstrated that the standards, as written, were too general. Accordingly, it was decided that the standards would be revised and redrafted and that an opportunity to comment on the revision would be made available.

Based on a review of all prior material and comments received at the hearings as well as during the period 1963-1966, an Interim Edition of the chapter containing the standards was prepared. Issued in February 1967, this version of the standards included revised provisions pertaining to community water supply wells which appeared in the preliminary edition in an appendix. Hearings on the Interim Edition were held in May 1967, and written comments were received as part of the record. These were also joint hearings with the Department of Public Health.

The eight hearings produced correspondence and an extensive file of transcripts containing information, opinions, and suggestions, which would fill several large volumes, if published. Since verbatim publication is impractical, a digest of what transpired has been prepared as Appendix A.

CHAPTER II. STANDARDS

The standards presented in this chapter are intended to apply to construction (including reconstruction) or destruction of wells throughout the State of California. Under certain circumstances, adequate protection of ground water quality may require more stringent standards than these presented here; under other circumstances, it may be necessary to deviate from the standards or substitute other measures which will provide protection equal to that provided by these standards. Since it is impractical to prepare standards for every conceivable situation, provision has been made in the succeeding material for deviation from the standards as well as for addition of appropriate supplementary standards. The need to deviate from general recommendations and to apply additional standards are the principal reasons that the Department is also investigating the development of different or supplemental water well construction standards for various subareas within the State. However, the Department believes that the standards presented in this report are satisfactory under most conditions for the construction and destruction of water wells in all areas of this state.

Part I. General

Section 1. Definitions.

A. Well or Water Well. As defined in Section 13710 of the Water Code, well or water well:

> " ... means any artificial excavation constructed by any method for the purpose of extracting water from, or injecting water into, the underground. This definition shall not include: (a) oil and gas wells, or geothermal wells constructed under the jurisdiction of the Department of Conservation, except those wells converted to use as water wells; or (b) wells used for the purpose of (1) dewatering excavation during construction, or (2) stabilizing hillsides or earth embankments."

B. Community Water Supply Well. A water well used to supply water for domestic purposes in systems subject to Chapter 7 of Part 1 of Division 5 of the California Health and Safety Code. (This definition includes wells commonly referred to as "Municipal Wells" or "City Wells".)

C. Individual Domestic Well. A water well used to supply water for domestic needs of an individual residence or commercial establishment such as an apartment house, cafe, gas station, etc.

D. Industrial Wells. Water wells used to supply industry on an individual basis (in contrast to supplies provided through community systems).

E. Agricultural Wells. Water wells used to supply water for irrigation or other agricultural purposes, including so-called "stock wells".

F. Recharge or Injection Wells. Wells constructed to introduce water into the ground as a means of replenishing ground water basins or repelling intrusion of seawater*.

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* Injection wells are also used to dispose of unusable waste water into unusable ground water bearing formations or dry, nonproductive formations. These wells can penetrate usable ground water zones; however, Water Code and Division 5 of the Health and Safety Code), such wells are not permitted to open into usable waters.

G. Air-conditioning Wells. Wells constructed to return to the ground, water which has been used as a coolant in air conditioning processes. Because the water introduced into these wells is degraded (from the standpoint of temperature), these wells have been construed as waste discharges and are therefore subject to the water quality control laws (Division 7 of the Water Code and Division 5 of the Health and Safety Code).

H. Horizontal Wells. Water wells drilled horizontally or at an angle with the horizon (as contrasted with the common vertical well). This definition does not apply to horizontal drains or "wells" constructed to remove subsurface water from hillsides, cuts, or fills (such installations are used to prevent or correct conditions that produce land slides).

I. Enforcing Agency. An agency designated by duly authorized local, regional or state government to administer laws or ordinances pertaining to well construction.

Section 2. Application to Type of Well.

Except as prescribed in Sections 3 and 4 (following) these standards shall apply to all types of wells described in Section 1. Before a change of use is made of a well, compliance shall be made with the requirements for the new use as specified herein.

Section 3. Exemption Due to Unusual Conditions.

If the enforcing agency finds that compliance with any of the requirements prescribed herein is impractical for a particular location because of unusual conditions and would result in construction of an unsatisfactory well, the enforcing agency may prescribe alternative requirements which are "equal to" these standards in terms of protection obtained.

Section 4. Exclusions.

The standards prescribed in Part II, "Construction", do not apply to test holes, observation wells, exploratory holes, salt-water (hydraulic) barrier injection or extraction wells. Note however that, Part III, "Well Destruction", does apply to these wells or holes.

Springs are excluded from these standards*.

Section 5. Special Standards.

A. In locations where existing geologic or ground water conditions require standards more restrictive than those described herein, or in addition to them, such special standards may be prescribed by the enforcing agency.

B. Special standards are necessary for the construction of injection wells, horizontal wells and other unusual types of wells, including galleries and other similar excavations. Design of these wells is subject to the approval of the enforcing agency.

Section 6. Well Drillers.

Wells shall be constructed by contractors licensed in accordance with the provisions of the Contractors License Law (Chapter 9, Division 3, of the Business and Professions Code) unless exempted by that act.

Section 7. Reports.

Reports concerning the construction of water wells shall be filed in accordance with the provisions of Sections 13750 through 13755 (Division 7, Chapter 7, Article 2) of the Water Code.

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* Methods which can be used to protect water supplies furnished by springs are described in "Manual of Individual Water Supply Systems", United States Public Health Service Publication No. 24, 1962.

PART II. Well Construction

Section 8. Well Location with Respect to Contaminants and Pollutants.

A. All wells shall be located an adequate horizontal distance from potential sources of contamination and pollution. Most of the factors involved in determining safe distances are usually not known. However, the following horizontal distances, which are based on past experience and general knowledge, are safe where dry upper unconsolidated formations, less permeable than sand, are encountered:*

	Community Water Supply Wells	Other Wells
Sewer, watertight septic tank, or pit privy	50 feet	50 feet
Subsurface sewage leaching field	100 feet	50 feet
Cesspool or seepage pit	150 feet	100 feet

Where in the opinion of the enforcing agency adverse conditions exist, the above distances shall be increased or special means of protection, particularly in the construction of the well, shall be provided.

B. In addition, if possible, the well shall be up the ground water gradient (upstream) from the specified sources of contamination.

C. When possible, the top of the casing shall terminate above any known conditions of flooding by drainage or runoff from the surrounding land.

D. Where a well is to be near a building, it shall be far enough from the building to be accessible for repair, maintenance, etc.

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* Because of the many variables involved in determination of the safe horizontal distance of a well from potential sources of contamination and pollution, no one set of distances will be adequate and reasonable for all conditions. In areas where adverse conditions exist, the distances listed should be increased. Conversely, where especially favorable conditions exist or where special means of protection, particularly in construction of the well, are provided, lesser distances may be acceptable if approved by the enforcing agency.

Section 9. Sealing the Upper Annular Space.

The space between the well casing and the wall of the drilled hole (the annular space) shall be effectively sealed to protect against contamination or pollution by surface and/or shallow, subsurface waters as set forth below.

A. Depth of Seal. Following is the minimum depth of seal below ground surface for various uses of wells:

Type	Depth of Seal (below ground surface)
Community Water Supply Wells	50 feet
Individual Domestic Wells	20 feet 1/
Industrial Wells	50 feet 1/ 2/
Agricultural Wells	None 3/
Air-Conditioning Wells	20 feet

1/ Exceptions are shallow wells where the water to be developed is at a depth less than 20 feet. In this instance, the depth of seal may be reduced but in no case less than 10 feet and special precautions shall be taken in locating the well with respect to possible sources of contamination.

2/ This requirement is necessary only where the water is used intentionally or incidentally for domestic purposes (drinking, washing, etc.) or the water must meet strict quality requirements for its intended uses.

3/ The annular space shall be sealed a minimum depth of 20 feet from the surface of the ground when the well is close to individual domestic wells or 50 feet when the well is close to sources of contamination or pollution described in Section 8. Local conditions, such as the existence of shallow, subsurface waters of undesirable quality, may warrant consideration of sealing the annular space around agricultural wells.

B. Sealing Conditions.* Following are requirements to be observed in sealing the annular space:

1. Wells that are fully situated, or at considerable depth, in unconsolidated, caving material.

a. Where the cable-tool method of drilling is used, an outer casing (conductor casing), may function as the seal provided the length of the conductor casing corresponds to the depth of seal specified in Part A of this section. (See Figure 1).

b. Where the rotary method of construction is used, the annular space shall be filled with sealing material to the depth specified in Part A of this section. When a temporary conductor casing is used to hold out the caving material during placement of the seal, it may be left in place or withdrawn as the sealing material is placed. (See Figure 1).

2. Wells that penetrate stratified formations. If an impervious (consolidated) formation is encountered within 5 feet of where the bottom of the seal described in Part A of this section should terminate, the seal should be extended into the impervious formation. (See Figure 1).

3. Gravel packed wells. In wells constructed without a conductor casing, the gravel pack shall terminate at the base of the seal. Gravel fill pipes may be installed in the seal. In wells constructed with a conductor casing (which allows the gravel pack to extend to the top of the well), the annular space between the conductor casing and the wall of the drilled hole shall be sealed to the depth specified in this section. (See Figure 1).

4. Wells that are fully situated in consolidated rock. (Open-bottom wells). An over-sized hole must be constructed to the depth and diameter required for the seal and casing installed to retain the seal (See Figure 1).

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* Methods of sealing are described in Appendix G.

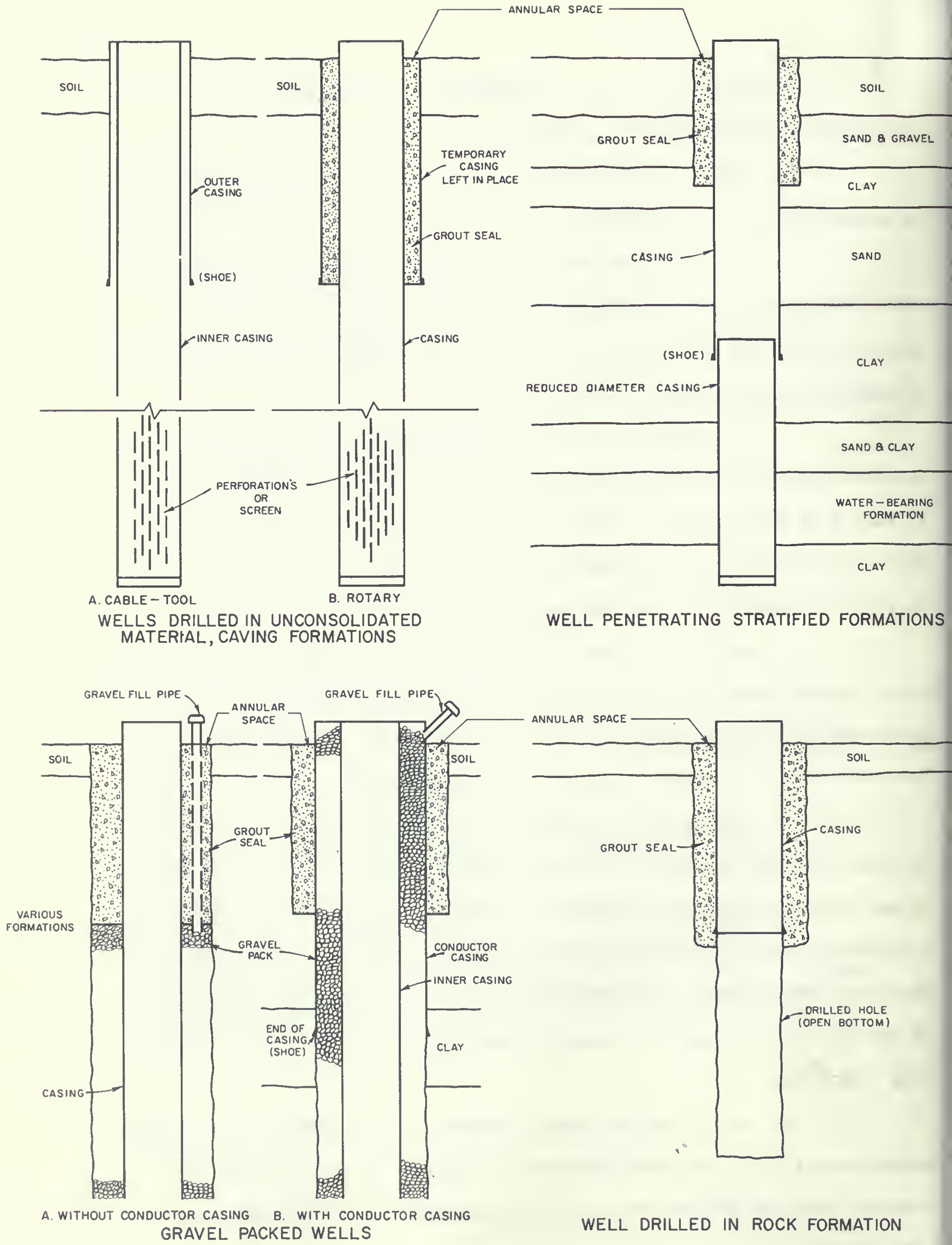

Figure I. SEALING CONDITIONS FOR UPPER ANNULAR SPACE

C. Conductor Casing. For community water supply wells, the minimum thickness of steel conductor casing shall be 1/4 inch for single casing or a minimum of No. 10 U. S. Standard Gage for double casing. Steel used for conductor casing shall conform to the specifications for steel casing described in Section 12.

D. Sealing Material. The sealing material shall consist of neat cement, cement grout, puddled clay, or concrete.* The neat cement mixture shall be composed of one bag of Portland Cement (94 pounds) to 5 to 7 gallons of clean water. Cement grout shall be composed of not more than two parts by weight of sand and one part of cement (per bag of cement) to 5 to 7 gallons of clean water. Quick-setting cement, retardents to setting, and other additives, including hydrated lime to make the mix more fluid (up to 10 percent of the volume of cement), and bentonite (up to 5 percent) to make the mix more fluid and to reduce shrinkage, may be used. Concrete used shall be "Class A" (6 sacks of Portland Cement per cubic yard) or "Class B" (5 sacks per cubic yard).

E. Thickness of Seal. The thickness of the seal shall be at least two (2) inches, and not less than three (3) times the size of the largest coarse aggregate used in the sealing material.

F. Placement of Seal. The sealing material shall be applied, if possible, in one continuous operation from the bottom of the interval to be sealed to the top.

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* Clay in the form of a mud-laden fluid is similar to and has the advantages of neat cement and cement grout. There is a disadvantage in that clay may separate out from the fluid. A bentonite-gelatenous mud is recommended. Concrete is useful in sealing large diameter wells, particularly where the width of annular ring is several inches or more. However, unless care is exercised during placement, the coarse aggregate may become separated from the cement.

Section 10. Surface Construction Features.

A. Openings. Openings into the top of the well which are not constructed to provide access to the well shall be sealed. Openings designed to provide access into well casings for making measurements, adding gravel, etc. shall be protected against entrance of surface waters by installation of watertight caps, and against entrance of foreign matter by installation of caps, plugs, screens, or downturned "U" bends.

1. Where the pump is installed directly over the casing, an annular watertight seal shall be placed between the pump head and the pump base (slab), or a watertight seal shall be placed between the pump base and the rim of the casing, or a seal or "well cap" shall be installed to close the annular opening between the casing and the pump column pipe.

2. Where the pump is offset from the well or where a submersible pump is used, the opening between the well casing and any pipes or cables which enter the well shall be closed by a watertight seal or "well cap".

3. All holes in the base of the pump which open into the well shall be sealed.

4. If the pump is not installed immediately upon completion of the well, or if there is a prolonged interruption in construction of the well, a watertight cap shall be provided at the top of the casing.

5. Pump discharge piping shall be located above the ground where possible; however, in the event of a below-ground discharge (below pump base), there shall be a watertight seal or gasket between the discharge pipe and well casing.

6. If a concrete base or slab (sometimes called a pump block or pump pedestal) is to be constructed around the top of the casing, it shall

be free from cracks or other defects likely to detract from its watertightness.

7. Where the well is to be gravel packed, a watertight cover shall be installed between the conductor pipe and the inner casing (if a conductor pipe is used) or between the casing and the well of the drilled hole, at the top of the well.

B. Well Pits. Because of their susceptability to contamination and pollution, the use of well pits should be avoided whenever possible. However, when a pit is necessary, the following requirements must be observed:

1. The bottom of the pit shall not extend below the water table.

2. The casing shall extend at least six inches above the pit floor.

3. The pit shall be constructed and protected so that rain, flood, or seepage waters cannot enter it.

4. The pit shall be provided with a drainage sump and an automatic sump pump (or, if topography permits, a "gravity" discharge). The discharge pipe from this sump shall not be connected to any sewer or pipe drain. The outlet of the discharge pipe shall not be below ground level, shall be above known conditions of flooding and protected against entry of small animals.

5. The top of the pit shall be provided with a watertight cover such as a concrete slab, metal cover, or house of equivalent watertight construction.

6. Each pit shall have easy access for proper operation, maintenance, and inspection of the equipment, and shall have a locked door or hatch to insure the public safety.

C. Enclosure of Well and Appurtenances. For community water supply wells, the well and pump shall be located in a locked enclosure to exclude access by unauthorized persons.

D. Pump Blowoff. When there is any blowoff or drain line from the pump discharge, it shall be so located that there is no hazard to the safety of the water supply by reason of flooding, back siphonage, or back pressure. The blowoff or drain line shall not be connected to any sewer.

Section 11. Disinfection and Other Sanitary Requirements.

A. Disinfection.* All community water supply, individual domestic, and industrial wells shall be disinfected following construction, repair, or when work is done on the pump, before the well is placed in service.

B. Gravel. Gravel used in gravel-packed wells shall come from clean sources and, except for agricultural wells, should be thoroughly washed before being placed in the well. Gravel purchased from a supplier should be washed at the pit or plant prior to delivery to the well site.

C. Lubricants. Mud and water used as a drilling lubricant shall be free from sewage contamination. Oil and water used for lubrication of the pump and pump bearing shall also be free from contamination.

Section 12. Casing.

A. Casing Material. Requirements pertaining to well casing are to insure that the casing will perform the functions for which it is designed, i.e., to maintain the hole by preventing its walls from collapsing, to provide a channel for the conveyance of the water, and to provide a measure of protection for the quality of the water pumped.

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* A procedure for disinfecting a well is described in Appendix E.

1. Well casing shall be strong and tough enough to resist the forces imposed during installation and those forces which can normally be expected after installation.

2. Steel is the material most frequently used for well casing, especially in drilled wells. There are three principal classifications of steel materials used for water well casing, and all are acceptable for use so long as they meet the following conditions.

a. Standard and line pipe.* This material shall meet one of the following specifications, including the latest revision thereof:

(1) API Std. 5L, "Specification for Line Pipe".

(2) API Std. 5LX, "Specification for High-Test Line Pipe".

(3) ASTM A53, "Standard Specification for Welded and Seamless Steel Pipe".

(4) ASTM A120, "Tentative Specifications for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses".

(5) ASTM A134, "Standard Specifications for Electric-Fusion (Arc)-Welded Steel Plate Pipe (sizes 16 inches and over)".

(6) ASTM A135, "Tentative Specifications for Electric-Resistance-Welded Steel Pipe".

(7) ASTM A139, "Standard Specifications for Electric-Fusion (Arc)-Welded Steel Pipe (sizes 4 inches and over)".

(8) ASTM A211, "Standard Specifications for Spiral-Welded Steel or Iron Pipe".

(9) AWWA C201, "AWWA Standard for Fabricated Electrically Welded Steel Pipe".

(10) AWWA C202, "Tentative Standard for Mill Type Steel Water Pipe".

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* Abbreviations used are: API-American Petroleum Institute; ASTM-American Society for Testing and Materials; AWWA-American Water Works Association.

b. Structural Steel. This material shall meet one of the following specifications of the American Society for Testing and Materials, including the latest revision thereof:

(1) ASTM A36, "Tentative Specification for Structural Steel".

(2) ASTM A242, "Tentative Specification for High Strength Low Alloy Structural Steel".

(3) ASTM A245, "Standard Specification for Flat-Rolled Carbon Steel Sheets of Structural Quality".

(4) ASTM A283, "Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality (Plate 2 inches and under in thickness)".

(5) ASTM A440, "Tentative Specification for High-Strength Structural Steel".

(6) ASTM A441, "Tentative Specification for High-Strength Low Alloy Structural Manganese Vanadium Steel".

c. High strength carbon steel sheets referred to by their manufacturers and fabricators as well casing steel. At present, there are no standard specifications concerning this material. However, the major steel producers market products whose chemical and physical properties are quite similar. Each sheet of material shall contain mill marking which will identify the manufacturer and specify that the material is well casing steel which complies with the chemical and physical properties published by the manufacturer.

d. The thickness of steel used for well casing shall be selected in accordance with good design practice as applied to conditions encountered in the area where the well is located. However, the thicknesses selected shall not be less than those set forth in the following table:

RECOMMENDED MINIMUM THICKNESSES
for
STEEL WELL CASING*
(single casing)

Diameter (inches)	Thickness (inches)
6	0.1046 (12 gage)
8	0.1046 (12 gage)
10	0.1046 (12 gage)
12	0.1345 (10 gage)
14	0.1345 (10 gage)
16	0.1644 (8 gage)
18	0.1644 (8 gage)
20	0.1644 (8 gage)
22	0.2500
24	0.2500
30	0.2500

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* Selection of casing depends on its ability to resist external forces as well as factors affecting the casing serviceability. The maximum theoretical external pressure under which a particular well casing of a specific diameter and thickness will collapse can be calculated. However, other considerations such as the effect of driving the casing into place or other impact forces which may have an effect on the ability of a particular casing to resist external pressures, cannot be calculated with accuracy. Good design practice precludes the selection of a casing of a particular thickness for use where it will experience external pressures approaching the maximum or where unknown forces might magnify the effect of the external forces. Instead it is customary for designers to introduce factors of safety which tend to insure that the casing selected will resist all probable forces imposed upon it. Consequently, experience and sound judgment, coupled with these factors of safety, have so far proved to be the best guide in selecting the proper casing. Suggested thicknesses for steel casing for various depths and diameters are to be found in material published by the various steel manufacturers and fabricators and in "Recommended Standards for Preparation of Water Well Construction Specifications", a publication of the Associated Drilling Contractors of the State of California. The suggested thicknesses contained in such publications are not to be considered a part of these standards.

3. Other materials*, except as listed in No. 4 below, may be used as casing for water wells, subject to the approval of the enforcing agency.

Concrete pipe should conform to the following specifications, including the latest revision thereof:**

(a) ASTM C14, "Standard Specifications for Concrete Sewer, Storm Drain, and Culvert Pipe".

(b) ASTM C76, "Tentative Specifications for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe".

(c) AWWA C300, "AWWA Standard for Reinforced Concrete Water Pipe-Steel Cylinder Type, Not Prestressed".

(d) AWWA C301, "AWWA Standard for Reinforced Concrete Water Pipe-Steel Cylinder Type, Prestressed".

4. Galvanized sheet metal pipe ("downspout"), or natural wood shall not be used as casing.

B. <u>Installation of Casing</u>. All casing shall be placed with sufficient care to avoid damage to casing sections and joints. Where casing is driven, (as is generally the case when the cable tool method of construction is used), the casing shall be equipped with a drive shoe at the lower end. All joints in the casing above perforations or screens shall be watertight. The uppermost perforations shall be at least below the depth specified in Section 9, Part A, "Depth of Seal".

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* Such as stainless steel, wrought iron, asbestos cement pipe, plastic pipe, fiber-glass pipe and synthetic woods, all of which have been successfully employed as casing in California or elsewhere. Their present use has been limited to special cases. Specifications for most of these materials are published by either ASTM or AWWA.

** ASTM - American Society for Testing and Materials.
AWWA - American Water Works Association.

Section 13. Sealing-off Strata.*

In areas where a well penetrates more than one aquifer and any of the aquifers contain water of a quality such that, if allowed to mix in sufficient quantity, will result in a significant deterioration of the quality of water in the other aquifer(s) or the quality of water produced, the strata producing such water shall be sealed off to prevent entrance of the water into the well or its migration to other aquifer(s).

A. The producing strata shall be sealed off by placing impervious material opposite the strata and opposite the confining formations for a sufficient vertical distance (but no less than 10 feet) in either direction, or, in the case of "bottom" waters, in the upward direction. Sufficient sealing material shall be applied to fill the annular space between the casing and the wall of the drilled hole in the interval to be sealed, and to fill the voids which might absorb the sealing material. The sealing material shall be placed from the bottom to the top of the interval to be sealed.

B. Sealing material shall consist of neat cement, cement grout, or other suitable impervious material. (See Section 9, Part D).

C. Sealing shall be accomplished by a method approved by the enforcing agency.*

Section 14. Well Development.

Developing, redeveloping, or conditioning of a well shall be done with care and by methods which will not cause damage to the well or cause adverse subsurface conditions that may destroy barriers to the vertical movement of water between aquifers.

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* Suggested methods for sealing-off strata are presented in Appendix F.

The following methods used in developing, redeveloping, or conditioning a well when done with care are acceptable: (a) overpumping, (b) surging by use of a plunger or compressed air, (c) backwashing or surging by alternately starting and stopping the pump, pouring water in the well or jetting with water, (d) introduction of chemicals designed for this purpose, and (e) a combination of the above.

Methods which produce an explosion are not prohibited; however, they should be used with care particularly where two or more distinct aquifers have been penetrated.

Where chemicals or explosives have been used, the well shall be pumped until all trace of these agents has been removed.

Section 15. Water Quality Sampling.*

The requirements to be followed with respect to water quality sampling are:

A. Community Water Supply Wells and Certain Industrial Wells. The water from all community water supply wells and industrial wells which provide water for use in food processing shall be sampled immediately following development and disinfection, and appropriate analysis shall be made. Approval of the enforcing agency must be obtained before the well is put into use.

1. Sample Tap. Except where there is free discharge from the pump (that is, there is no direct connection to the water delivery system), a sample tap shall be provided on this discharge line so that water representative of the water in the well may be drawn for laboratory analysis.

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* The collection of water quality samples is described in Appendix G.

2. Laboratory Analysis. The appropriate analysis shall be performed by a laboratory certified by the California Department of Public Health. A copy of the laboratory analysis shall be forwarded to the California Department of Public Health or to the Local Health Department.

3. Bacterial Quality. Where the water is to be used for domestic purposes, samples shall be collected for bacteriological analysis (presence of coliform organism) after all traces of development and disinfectant chemicals have been removed from the well.

4. Chemical (Mineral) Quality. Where the water is to be used for domestic purposes or for food processing, samples shall be collected for chemical analysis.

B. Other Types of Wells. To determine the quality of ground water which will be available from the well and its suitability for intended uses, the water in all wells should be sampled immediately following construction and development, and appropriate analyses based upon the intended uses should be made. Where the water is to be used for domestic purposes, samples should be collected for bacteriological analysis (presence of coliform organism) after all traces of development or disinfectant chemicals have been removed from the well. Determination of the mineral quality of the water produced by the well is desirable from the standpoint of all uses.

Section 16. Special Provisions for Large Diameter Shallow Wells.

A. Use as Community Water Supply Wells. The use of bored or dug wells, or wells less than 50 feet deep, to provide community water supplies shall be avoided unless there is no other feasible means for obtaining water. When used for this purpose, these wells shall be located at least 250 feet from any underground sewage disposal facility.

B. Bored Wells. All bored wells shall be cased with concrete pipe or steel casing whose joints are watertight from 6 inches above surface to the depths specified in Section 9, Part A. The space between the wall of the hole and the casing shall be filled with concrete to the depths specified in Section 9, Part A. The minimum thickness of the surrounding concrete seal shall be 3 inches.

C. Dug Wells. All dug wells shall be "curbed" with a watertight curbing extending from the surface to the depths specified in Section 9, Part A. The curbing shall be of concrete poured-in-place or of casing (either precast concrete pipe or steel) surrounded on the outside by concrete.

If the curbing is to be made of concrete, poured-in-place, it shall not be less than six inches thick. If precast concrete pipe or steel casing is used as part of the curbing, the space between the wall of the hole and the casing shall be filled with concrete to the depths specified in Section 9, Part A. The minimum thickness of the surrounding concrete shall be four inches.

D. Casing Material. Either steel or concrete may be used for casing bored or dug wells.

1. Steel used in the manufacture of casing for bored and dug wells should conform to the specifications for casing material described in Section 10. Minimum thickness of steel casing for dug wells shall be in accordance with the following table:

MINIMUM THICKNESS OF STEEL
CASING FOR BORED AND DUG WELLS

Diameter, in inches	U. S. standard gage or plate thickness
18	8 gage
24	1/4 inch
30	1/4 inch
36	1/4 inch
42	1/4 inch
48	1/4 inch

2. Concrete casing can consist of either poured-in-place concrete or precast concrete pipe. Poured-in-place concrete should be sufficiently strong to withstand the earth and water pressures imposed on it. It should be properly reinforced with steel to furnish tensile strength and to resist cracking, and it should be free from honeycombing or other defects likely to impair the ability of the concrete structure to remain watertight. Aggregate small enough to insure proper placement without "bridging" should be used.

Precast concrete pipe is usually composed of concrete rings from 1 to 6 feet in diameter and approximately 3 to 8 feet long. To serve satisfactorily as casing, these rings should be free of any blemishes that would impair their strength or serviceability. In the portion of the well that is to be sealed (see paragraphs B and C of this section), the joints shall be made watertight. Concrete pipe shall conform to the specifications listed in Section 12, Part A, item 3.

E. Covers. All bored and dug wells shall be provided with a structurally sound, watertight, cover made of concrete or steel.

Section 17. Special Provisions for Driven Wells.

A. If the well is to be used as an individual domestic well, an oversize hole with a diameter at least three inches greater than the diameter of the pipe shall be constructed to a depth of six feet and the annular space around the pipe shall be filled with neat cement, cement grout, or a bentonite mud.

B. The minimum wall thickness of steel drive pipe shall be not less than 0.140 inches.

Section 18. Repair or Deepening of Wells.

A. All casing used in the deepening or repair of wells shall meet the requirements of Section 12, "Casing", of these provisions.

B. If the old casing is removed, the well shall be recased and sealed in accordance with the requirements of Section 9, Part A.

Section 19. Temporary Cover.

Whenever there is an interruption in work on the well such as overnight shutdown, during inclement weather, or waiting periods required for the setting up of sealing materials, for tests, for installation of the pump, etc., the well opening shall be closed with a cover to prevent the introduction of undesirable material into the well and to insure the public safety.

During interruptions of one week or more, a semipermanent cover shall be installed. For wells cased with steel, a steel cover, tack-welded to the top of the casing, is adequate.

Part III. Destruction of Wells

Section 20. Purpose of Destruction.

Proper destruction of a well that is no longer useful serves two main purposes:

1. To assure that the ground water supply is protected and preserved for further use.

2. To eliminate the potential physical hazard that exists.

Section 21. Definition of "Abandoned" Well.

A well is considered "abandoned" when it has not been used for a period of one year, unless the owner declares his intention to use the well again for supplying water or other associated purpose* (such as an observation well or injection well). As evidence of his intentions for continued use, the owner shall properly maintain the well in such a way that:

1. The well has no defects which will facilitate the impairment of quality of water in the well or in the water-bearing formations penetrated.
2. The well is covered with an appropriate locked cap.
3. The well is marked so that it can be clearly seen.
4. The area surrounding the well is kept clear of brush or debris.

If the pump has been removed for repair or replacement, the well shall not be considered "abandoned", provided that evidence of repair can be shown. During the repair period, the well shall be adequately covered to prevent injury to people and to prevent the entrance of undesirable water or foreign matter.

Observation wells used in the investigation or management of ground water basins by governmental agencies or other appropriate engineering or research organizations are not considered "abandoned" so long as they are maintained for this purpose. However, such wells shall be covered with

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* Although it should be obvious, the reader is reminded that an "abandoned" well should never be used for the disposal of trash, garbage, sewage (except where sewage is reclaimed for recharging the ground water basin, and then only in accordance with the provisions of Section 4458 of the California Health and Safety Code), etc.

an appropriate cap, bearing the label, "Observation Well", and the name of the agency or organization, and preferably shall be locked when measurements are not being made. When these wells are no longer used for this purpose or for supplying water, they shall be considered "abandoned".

Section 22. General Requirement.

All "abandoned" wells shall be destroyed in such a way that they will not produce water or act as a channel for the interchange of waters, when such interchange will result in significant deterioration of the quality of water in any or all water-bearing formations penetrated, or present a hazard to the safety and well being of people and of animals.

Destruction of a well shall consist of the complete filling of the well in accordance with the procedures described in Section 23 (following).

Section 23. Requirements for Destroying Wells.

A. Objective. The objective of the requirements described in this section is to restore as nearly as possible those subsurface conditions which existed before the well was constructed taking into account also changes, if any, which have occurred since the time of construction. (For example, an aquifer which may have produced good quality water at one time but which now produces water of inferior quality, such as a coastal aquifer that has been invaded by seawater.)

B. Preliminary Work. Before the hole is filled, the well shall be investigated to determine its condition, details of construction, and whether there are obstructions that will interfere with the process of filling and sealing.

1. If there are any obstructions, they shall be removed, if possible, by cleaning out the hole or by redrilling.

2. Where necessary, to insure that sealing material fills not only the well casing but also any annular space or nearby voids, the casing should be perforated or otherwise punctured.

3. In drilled wells, it may be necessary or desirable to remove some of the casing. However, in some cases this can be done only as the well is filled. In dug wells, as much of the lining as possible should be removed prior to filling.

C. Filling and Sealing Conditions. Following are requirements to be observed when certain conditions are encountered:

1. Well wholly situated in unconsolidated material in an unconfined ground water zone. If the ground water supplies are within 50 feet of the surface, the upper 20 feet shall be sealed with impervious material and the remainder of the well shall be filled with clay, sand, or other suitable inorganic material.

2. Well penetrating several aquifers or formations. In all cases the upper 20 feet of the well shall be sealed with impervious material.

In areas where the interchange of water between aquifers will result in a significant deterioration of the quality of water in one or more aquifers, or will result in a loss of artesian pressure, the well shall be filled and sealed so as to prevent such interchange. Sand or other suitable inorganic material may be placed opposite the producing aquifers (or formations) and other formations where impervious sealing material is not required. Impervious material must be placed opposite confining formations for a sufficient vertical distance (but in no case less than 10 feet) in either direction to prevent the vertical movement of water from the producing formation. The formation producing the deleterious water shall be sealed by placing impervious material opposite the formation, and opposite the confining formations for a sufficient vertical distance (but no less than 10 feet) in either direction, or, in the case of "bottom" waters, in the upward direction.*

In locations where interchange is in no way detrimental, suitable inorganic material may be placed opposite the formations penetrated. When the boundaries of the various formations are unknown, alternate layers of impervious and pervious material shall be placed in the well.

3. Well penetrating creviced or fractured rock. If creviced or fractured rock formations are encountered just below the surface, the portions of the well opposite this formation shall be sealed with neat cement, cement grout, or concrete. If these formations extend to considerable depth,

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* Determining the significance of interchange of waters whose qualities vary and of the loss of artesian pressures, requires extensive knowledge of the ground water basin in question. The Department of Water Resources has over the years, and frequently in cooperation with agencies such as the United States Geological Survey, undertaken a number of ground water studies and amassed considerable information and data about the subject. Although much is known about the State's ground water supplies, detailed studies sufficiently accurate to define interchange problems have been made only in certain areas. In still other areas, there is only partial definition of the problem. Example of areas where definition has been made are the coastal plain of Los Angeles County and the eastern part of the Santa Clara Valley in Alameda County. Recommendations for water well standards for these areas have been published by the Department. (Alameda County, Bulletin No. 74-2; Central, Hollywood, and Santa Monica Basins, Los Angeles County, Bulletin No. 74-4; and West Coast Basin, Los Angeles County, Bulletin No. 107). An excellent example of a "bottom" water is the saline connate water underlying the Central Valley at varying depths.

alternate layers of coarse stone* and cement grout or concrete may be used to fill the well. Fine grained material shall not be used as fill material for creviced or fractured rock formations.

4. Well in noncreviced, consolidated formation. The upper 20 feet of a well in a noncreviced, consolidated formation shall be filled with impervious material. The remainder of the well may be filled with clay or other suitable inorganic material.

5. Well penetrating specific aquifers, local conditions. Under certain local conditions, the enforcing agency may require that specific aquifers or formations be sealed off during destruction of the well.

D. Placement of Material. The following requirements shall be observed in placing fill or sealing material in wells to be destroyed:

1. The well shall be filled with the appropriate material (as described in item E of this section) from the bottom of the well up.

2. Where neat cement, cement grout, or concrete is used, it shall be poured in one continuous operation.

3. Sealing material shall be placed in the interval or intervals to be sealed by methods that prevent free fall, dilution, and/or separation of aggregates from cementing materials.

4. Where the head (pressure) producing flow is great, special care and special methods must be used to restrict the flow while placing the sealing material. In such cases, the casing must be perforated opposite the area to be sealed and the sealing material forced out under pressure into the surrounding formation.

5. In destroying gravel-packed wells, the casing shall be

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* The limiting dimensions of coarse stone are usually considered to range between $\frac{1}{4}$ and 3 inches.

perforated or otherwise punctured opposite the area to be sealed. The sealing material shall then be placed within the casing, completely filling the portion adjacent to the area to be sealed and then forced out under pressure into the gravel envelope.

6. When pressure is applied to force sealing material into the annular space, the pressure shall be maintained for a length of time sufficient for the cementing mixture to set.

7. To assure that the well is filled and that there has been no jamming or "bridging" of the material, verification shall be made that the volume of material placed in the well installation at least equals the volume of the empty hole.

E. Materials. Requirements for sealing and fill materials are as follows:

1. Impervious Sealing Materials. No material is completely impervious. However, sealing materials shall have such a low permeability that the volume of water passing through them is of small consequence.

Suitable materials include neat cement, cement grout, concrete, bentonite clays (muds), silt and clays, well-proportioned mixes of silts, sands, and clays (or cement), and native soils and natural material that have a coefficient of permeability of less than 100 feet per year.* Used drilling muds are not acceptable.

A neat cement mixture shall be composed of one bag of Portland Cement to 5 to 7 gallons of clean water. Cement grout shall be composed of not more than two parts of sand and one part of cement (per bag of cement) to 5 to 7 gallons of clean water. Concrete used shall be "Class A" (6 sacks

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* Examples of materials of this type are: very fine sand with a large percentage of silt or clay, inorganic silts, mixtures of silt and clay, and clay. Native materials should not be used when the sealing operation involves the use of pressure.

of Portland Cement per cubic yard) or "Class B" (5 sacks per cubic yard).

2. Fill Material. Many materials are suitable for use as a filler in destroying wells. These include clay, silt, sand, gravel, crushed stone, native soils, mixtures of the aforementioned types, and those described in the preceding paragraph. Material containing organic matter shall not be used.

F. Additional Requirements for Wells in Urban Areas. In incorporated areas or unincorporated areas developed for multiple habitation, to make further use of the well site, the following additional requirements must be met:

1. A hole shall be excavated around the well casing to a depth of six feet below the ground surface and the well casing removed to within six inches of the bottom of the excavation.

2. The sealing material used for the upper portion of the well shall be allowed to spill over into the excavation to form a cap at least one foot thick.

3. After the well has been properly filled, including sufficient time for sealing material in the excavation to set, the excavation shall be filled with native soil.

G. Temporary Cover. During periods when no work is being done on the well, such as overnight or while waiting for sealing material to set, the well and surrounding excavation, if any, shall be covered. The cover shall be sufficiently strong and well enough anchored to prevent the introduction of foreign material into the well and to protect the public from a potentially hazardous situation.

CHAPTER III. FACTORS INVOLVED IN FORMULATING STANDARDS

The standards for the construction of water wells and destruction of abandoned wells recommended in this report were based on consideration of: (1) ground water geology and hydrology, (2) impairment to ground water quality, and (3) water well construction practices. Their significance to the determination of well standards for California is described in this chapter.

Ground Water Geology and Hydrology

Occurrence of Ground Water in California

Ground water in California occurs in a variety of rock types, and under diverse conditions. Most of the readily available water occurs in ground water reservoirs consisting of unconsolidated alluvial fill materials which underlie valley floor areas throughout the State. In coastal areas, the alluvial fill materials are frequently interbedded with unconsolidated marine sands and gravels with silt and clay interbeds. In most cases, the valley and coastal areas are surrounded and underlain at depth by virtually impermeable rocks. In many areas, the unconsolidated sediments are underlain and bordered by extensive deposits of older, generally more consolidated, sedimentary materials. These deposits are also water-bearing and function, in part, as recharge areas for the ground water reservoirs.

Of less significance with respect to the production of ground water in the State, but often of local importance, are sedimentary materials which were deposited in lakes or lagoons, or as sand dunes, marine terrace deposits, glacial deposits, shallow water marine sediments from which sea water has been flushed, and Recent and Pleistocene volcanic rocks. The remainder of the rock types in California are considered to be essentially nonwater-bearing, although they may yield limited quantities of water to wells from fractures, joints, faults and weathered zones.

A more detailed description of the occurrence of ground water in California is presented in Appendix B.

Subsurface Hydrologic Conditions

Aquifers are those permeable strata which will yield sufficient quantities of ground water to wells to be of significance as a source of water supply. One or more aquifers may be contained within a ground water basin or subsurface water storage reservoir. In the coastal plain of Los Angeles County, for example, water is being obtained from a sequence of 11 aquifers. Aquifers and the ground water contained in them may occur under unconfined or confined conditions. Figure 2 is a diagrammatic cross section illustrating these subsurface hydrologic conditions.

Unconfined aquifers consist of strata of water-bearing materials that are not overlain by impervious materials. The ground water they contain is usually never under pressure. An unconfined aquifer may be underlain by aquifers that are confined. Elevation of water surface in a nonpumping well penetrating an unconfined ground water body corresponds approximately to the elevation of the water table (See Figure 2).

Perched ground water is a special case of unconfined water. Perched ground water occurs in aquifers that are suspended above the principal zone of saturation by impervious, general clayey layers (Figure 2).

Confined aquifers consist of strata of water-bearing materials that are overlain, and generally underlain, by material sufficiently

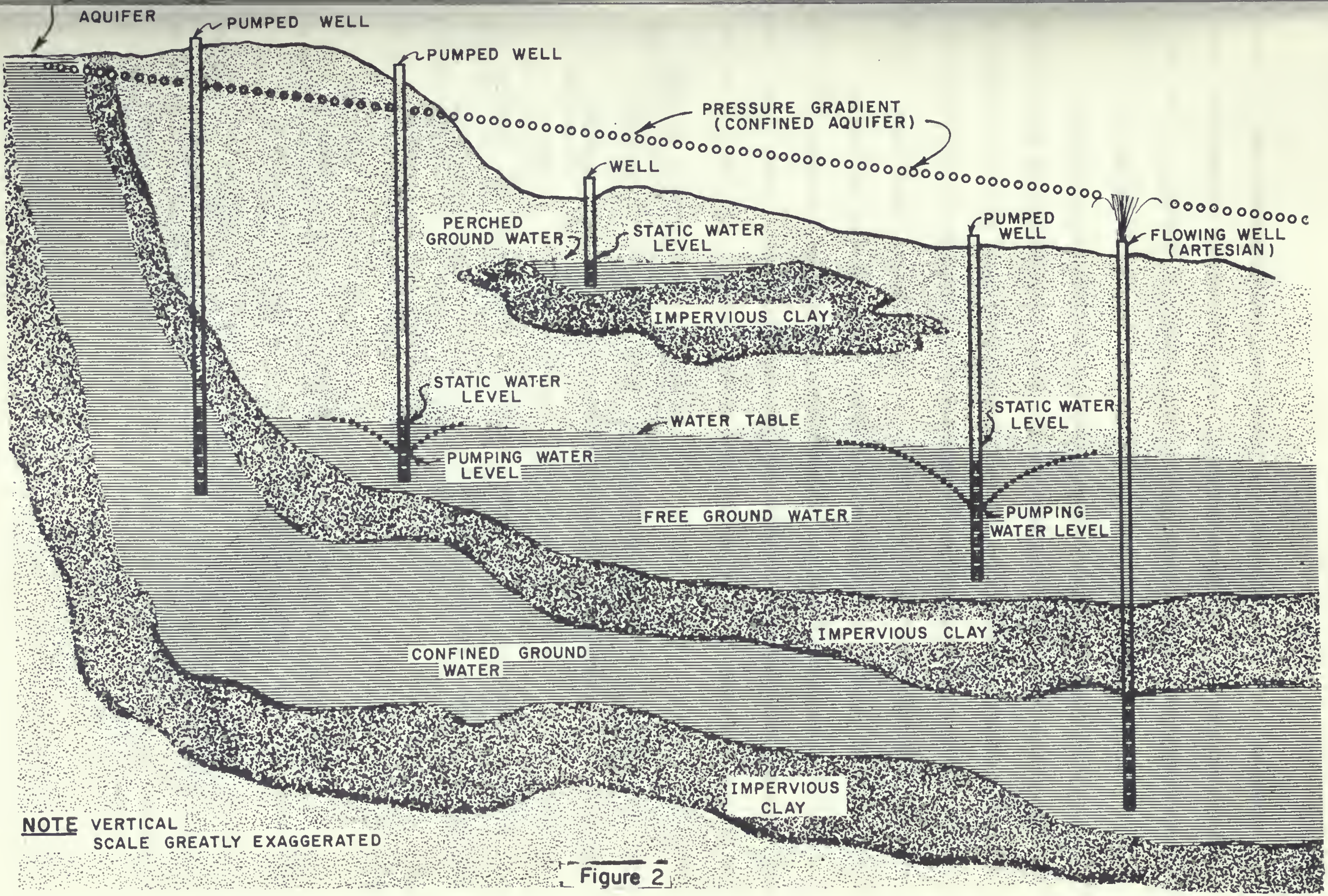

Figure 2

DIAGRAMMATIC CROSS-SECTION SHOWING FREE, CONFINED AND PERCHED GROUND WATER CONDITIONS.

impervious to sever free hydraulic connection with other aquifers or ground water bodies or the ground surface. Ground water in a confined aquifer normally is under pressure, but if this pressure has been sufficiently reduced by pumping to lower the static water level below the bottom of the overlying impervious stratum, the water is no longer under pressure. A confined aquifer usually cannot be recharged by the vertical movement of water from the ground surface (Figure 2).

A confined aquifer under pressure may be compared to a large capacity pipeline conveying water. Water in such a conduit would move under the influence of the pressure head differential between the intake and discharge points. Similarly, under ordinary conditions of supply and demand, ground water under pressure in a confined aquifer moves from the intake or forebay area of the aquifer to the discharge area. The pressure at any point within the confined aquifer is the elevation to which water would rise in a nonpumping well penetrating the particular aquifer. Elevation of the pressure (piezometric) surface of a particular confined ground water body is independent of water surface elevations of other overlying or underlying ground waters. Under some conditions, the pressure surface may be above the ground surface, in which case water would flow from a well penetrating the confined aquifer. Such a well is termed a flowing or artesian well (Figure 2).

As is to be expected, in many locations in California there is much variation from these ideal conditions of confined and unconfined aquifers. The alluvial deposits, from which most water is pumped, are generally composed of lenses and stringers of sand and gravel with discontinuous layers and lenses of less permeable materials high in fines such as clay. Even extensive confining layers can leak in the direction of the vertical hydraulic gradient. In some cases, the permeability of the layer of fine material is significant enough that the underlying aquifer is called a semiconfined or partially confined aquifer.

Confined aquifers often occur in the central area of inland ground water basins and in the seaward portions of coastal basins. Fine-grained, relatively impermeable lake beds and marine sediments may overlie more permeable strata in these areas, causing confinement of water beneath them.

Openings in volcanic rocks may be of significant size, giving the rocks high permeability and permitting little filtering of water. If such volcanic rocks are overlain by impermeable materials, the volcanic aquifer is confined.

Characteristics of Ground Water Quality

The quality characteristics of ground water are categorized as biological, physical, and mineral.

Biological. Bacteria are involved in the production of carbon dioxide, the oxidation of nitrogen, and the reduction of sulfate, iron, and nitrate as part of the decomposition process and are found in ground waters under certain conditions. Their presence is derived from soil and rock particles in which they grow. Most of these bacteria have little or no effect on beneficial uses of water, except for some industrial processes. A few, however, such as iron and sulfur bacteria, are detrimental for domestic and industrial purposes and may cause well screens, perforations, gravel packing, and voids in the surrounding formation material to become clogged. Sulfur bacteria also contribute to the corrosion of metal surfaces and concrete, and iron bacteria will augment the corrosion of iron and steel.

Of most concern, however, are the pathogenic, or disease-producing, bacteria. These bacteria are not normally found in ground water, consequently their presence is indicative of contamination in and around the well (or wells).

Occasionally viruses have been found in well waters. As with pathogenic bacteria their presence indicates contamination. So far as is known, although other types of viruses are found in water, only infectious hepatitis viruses have been associated with waterborne disease outbreaks.

Physical. The principal physical characteristics of ground water of interest to domestic users are taste, odor, color and temperature. Taste, odor, and color, which relate to esthetic values, are dependent on such factors as temperature, kinds and abundance of bacteria, and type and concentration of minerals in the water. Some ground waters by nature possess disagreeable tastes and odors and are not crystal clear. Most familiar are those containing significant amounts of iron and manganese in solution (which impart a metallic taste and reddish stain) and hydrogen sulfide (which imparts a "rotten egg" odor).

The temperature of ground water remains relatively constant, seldom changing more than 3 or 4 degress Fahrenheit during a year, a characteristic very desirable for water used for cooling. At depths of 30 to 60 feet the temperature of ground water is about 2 or 3 degrees Fahrenheit higher than the mean annual air temperature. The temperature of ground water increases naturally with depth about one degree Centigrade for each 100 feet.

Mineral. The mineral quality of native ground water is a variable characteristic and is influenced to a great degree by the amount of precipitation and the geologic conditions found in each area. In general, the concentration of mineral constituents in ground water is governed by: (1) the quantity of infiltrating water, (2) the surface area of the rock and soil particles with which the water comes in contact, (3) the time of contact between the water and the soil particles, and (4) the kind and proportion of mineral constituents in the composition of the rocks and soils.

Mineral quality of native ground waters may also reflect the characteristics of surface streams tributary to the ground water basin. Ground waters in areas of plentiful precipitation, or in areas underlain by igneous rock materials, generally contain the least amount of soluble minerals. On the other hand, ground waters in areas of light precipitation, of restricted subsurface drainage, of poorly consolidated marine deposits, or combinations thereof, are generally characterized by substantial concentrations of mineral constituents. Although there is normally a regional or areal similarity in the mineral quality of ground water, there may be localized or even extensive variance of mineral quality within an area, which is the result of natural conditions or of man's activities. Similarly, there may be vertical variation in mineral quality as is often the case where there are multiple aquifers or zones.

Under certain conditions, dissolved minerals and gases in water (as well as the previously described bacteria) of sufficient kinds and concentrations tend to foster corrosion and clogging problems in wells. When the balance of dissolved substances in water is upset, some minerals come out of solution and are deposited as incrustations on well casings, screens and perforations, and pump assemblies. The most common mineral incrustations involve the precipitation of the carbonates and sulfates of calcium and magnesium. Such incrustations lead to a marked decrease in the productivity of wells, and if heavy enough, may eventually result in shut-down for repair, cleaning or replacement.

Results of bacteriological, physical, and mineral analyses of ground water indicate whether the water is suitable (or safe, as the case may be) for domestic purposes and for some industrial uses. Similarly, results of physical and mineral analyses will determine the suitability of ground water for other industrial uses. In the case of irrigation, where the use of sewage is not involved, only mineral analyses are considered.

Impairment to Ground Water Quality

To preserve the usefulness of this valuable water supply, the quality of ground water must be maintained at a level suitable for a wide variety of beneficial uses, each of which has individual requirements. In order to maintain suitable quality in our ground waters, we must consider water quality criteria, and the sources of quality impairment to these waters, with particular reference to the ways in which water wells may contribute to quality impairment.

Quality requirements for various beneficial uses are not necessarily rigid; they may be influenced by numerous factors which vary from one area to another. Irrigation water quality requirements, for example, are affected by climatological conditions, type of crop, soil conditions, and other variables. Criteria commonly used for evaluating suitability of water for domestic, industrial, and irrigation uses are presented in Appendix H.

To help clarify the problem of ground water quality maintenance, a discussion of the major sources of impairment to the quality of ground water follows.

Surface Water

Surface waters can cause impairment of the quality of water in wells, or to the quality of ground water, both directly and indirectly.

Surface waters which represent direct sources of degradation are flood waters, drainage from barnyards and city streets, and runoff from irrigated fields that, more likely than not, have been fertilized or sprayed with insecticides. By their very nature, these waters contain the waste products of man's activities and as such are potential sources of contamination or pollution to water in wells. Sewage as a source of impairment is discussed later. Surface waters gain access to ground water through wells either by overtopping the casing, or by flowing downward in the channel between the casing and the wall of the drilled hole.

Natural leaching, the process by which water removes soluble material from soils and geologic formations, also can contribute to ground water quality degradation. This degradation takes place when precipitation and runoff, on infiltrating the soil or formation on the way to the zone of saturation, pick up excessive soluble mineral constituents of the soil. This excessive concentration of soluble salts when added to the ground water body may alter and degrade it.

Another form of leaching takes place in the process of irrigation.

Part of the water applied during irrigation is consumed by evapotranspiration of plant life, part runs off, and part infiltrates the soil. The percolate carries practically all the salts contained in the applied water, as only a small portion of the total salts is utilized in plant growth. The percolate also has a tendency to become more highly mineralized by leaching minerals from the soil or those applied to the soil such as fertilizers or soil conditioners.

Concentrated waters resulting from leaching may enter aquifers and degrade the quality of fresh waters; or they may accumulate on impermeable layers of clay as perched ground waters and thereby be restrained from entering the main water body. Poorly constructed water wells, penetrating both perched aquifers and underlying aquifers, may remove this restraint and permit flow of the inferior quality perched waters into the principal aquifers.

The increase of nitrates in ground water supplies at various locations in California illustrates the effects of leaching. Nitrates in sufficient concentration are contaminents in drinking water and are detrimental to certain industrial processes. Their presence in the soil is derived from natural decomposition of organic matter, chemical fertilizers, manures and other livestock waste, and sewage and industrial wastes (via ponds, sewer farms, septic tanks, etc). Generally, most native ground waters of California contain only small amounts of nitrates. Through the process of leaching and percolation, nitrates from the soil have reached the underlying ground waters more readily in some locations than others. Public awareness that nitrates in ground water are a potential problem in certain areas of California is only of recent origin. Particular attention has been given to areas of Southern California [20] [29] [45] and the San Joaquin Valley [53].

The leaching of waste materials disposed of in dumps, pits, etc., is discussed in a succeeding section.

Sewage and Industrial Wastes

Improper disposal of sewage or industrial wastes onto or below ground surface presents a potential source of impairment to the quality of ground water and could harmfully affect public health as well as adversely affect other beneficial uses.

Impairment of ground water quality by domestic sewage is primarily in the form of bacterial or viral contamination, although, as discussed later, the presence of synthetic detergents in these wastes has presented a problem. Further, industrial wastes discharged either in combination with domestic sewage or separately may also significantly impair ground water quality. Information is available which indicates that bacterial contamination is restricted to a localized area around the source of contamination and does not ordinarily affect extensive areas, particularly when the discharge is into granular materials. This generalization does not hold true for limestone, lava, or fractured rock formations where large underground solution caverns, tubes, or fractures may exist.

Studies have also indicated that bacteria will travel in the direction of ground water flow. In an investigation of travel of pollution conducted at the Richmond Field Station of the University of California and completed in 1954 [32], researchers found that, under the soil conditions at the station, coliform bacteria traveled laterally a maximum distance of about 100 feet when sewage was introduced under pressure directly into a water-bearing formation. Other researchers have found that, under different conditions, bacteria traveled up to 232 feet from the source of pollution when introduced into the water-bearing formation.

Disposal of sewage to coarse-grained, uniform-sized gravels, channelized or creviced rock formations, such as some limestone deposits or lava flows, or disposal directly to coarse-grained water-bearing materials through recharge wells, may permit ready access of bacteria to ground water and allow the bacteria to travel greater distances than in less porous formations. Surveys of epidemics caused by ground water contamination indicate that in many cases, bacteria have traveled considerably greater distances than those reported in experiments described above.

Although it has been amply demonstrated that viruses are carried in sewage and that epidemics of infectious hepatitis have been caused by contaminated ground waters, field tests have not been made to determine the travel of viruses in ground water. This is because the viral test is not easily accomplished.

Proper construction techniques can minimize the possibility of bacterial or viral contamination of a well. This matter, although it is an extremely important public health problem, does not present a quality problem which involves the basin-wide protection of the quality of ground waters.

While of less significance from the standpoint of public health and safety than bacterial contamination, pollution of ground water by synthetic detergents has been an important problem although it is becoming less severe with time. Synthetic detergents, particularly those in which ABS* is the surface active agent, in domestic water supplies cause foaming, unpleasant tastes, and other undesirable esthetic effects. This is because ABS and similar compounds do not break down biologically in water. Their appearance in sewage is rather recent, having occurred in significant amounts only over the past 19 years, the period since they were introduced for public use. Of particular interest is that their presence in water is evident before the presence of bacteria is detected. Thus, they serve as an early indicator of pollution by sewage.

Industry believes it has found the answer to the detergent problem in LAS** which replaced ABS in late 1965. The structure of LAS is such that detergent wastes containing it should decompose readily by bacterial action. However, the conversion to LAS has been too recent to determine the degree of success achieved so far as ground waters are concerned.

The movement (distance and direction of travel) and persistence of synthetic detergents in ground water is the subject of much study and research in California as well as elsewhere [65].

Industrial wastes present a source of more lasting impairment of quality than domestic sewage because they are likely to contain substances in more harmful concentrations and more toxic or deleterious chemical constituents than those usually found in domestic sewage. Whereas movement through soil or sand removes bacteria, such percolation has little or no effect on many constituents. Examples of chemicals traveling hundreds of feet to several miles through porous formations have been recorded. Once the quality of water in a portion of a ground water basin is degraded by mineralized waters, restoration of the basin to its natural condition

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* ABS - Alkyl benzene sulfonate

** LAS - Linear alkylate sulfonate

is very difficult and often economically or technically unfeasible.

An example of impairment due to industrial wastes occurred near Denver, Colorado (65) (72). Chemical contaminants, which were discharged to waste disposal ponds, infiltrated to the underlying free ground water zone over a 14-year period. Although corrective measures were applied in 1955, the toxic effects of these chemicals on crops irrigated with ground water were still evident in some areas in 1962, even though the affected ground water had not been used for irrigation for about six years. The ground water is unfit as a source of domestic water supply. The total area affected amounts to approximately 6½ square miles. The chemical front, which has migrated as much as five miles from the waste ponds, continues to be a serious problem to water users in the affected area. Unfortunately, firm supplies of diluting water are not available in this area. The condition will persist until the pollutants are flushed naturally out of the basin, or are sufficiently mixed with the ground water to the point where they are no longer a problem.

It is interesting to note that, in the few instances where these chemicals were reported as being present in a deeper, confined zone, their presence is attributed to places "where old wells have been abandoned, or where damaged or improperly sealed well casings have locally permitted infiltration of the toxic water through the confining layers". (72)

A number of such incidents involving the movement of "slugs" of industrial waste waters in California, as well as many other states have been reported (46) (65).

This discussion is not intended to imply that the infiltration or introduction of any or all waste waters to ground water is to be avoided.

On the contrary, there are a number of instances particularly in Southern California where nontoxic, treated waste waters of reasonably good mineral quality have been used to recharge dwindling ground water supplies. Injection of waste water into the ground for recharge is subject to control by the appropriate Regional Water Quality Control Board and requires approval by the State Board of Public Health (Section 4458 of the Health and Safety Code).

Where ground water is unconfined, waste waters can reach the zone of saturation by moving in a generally vertical direction through permeable materials. Where ground water is confined, waste waters are prevented from moving directly downward by the overlying confining strata. However, waste waters can gain easy access to either unconfined or confined aquifers when defective or poorly constructed wells provide clear channels.

Solid Wastes

The disposal of solid wastes in refuse dumps, pits, and the like (in itself a growing problem in the metropolitan areas of the world) can contribute to the impairment of ground water quality. This is because infiltrating waters dissolve the decomposing matter (inorganic as well as organic) and carry the solutes with them as they percolate to the water table. Worse yet, the water table may actually intercept, or be intercepted by, the dump, resulting in direct dissolution of the material and subsequent movement of the concentrate downstream. Such a situation can be aggravated when dump sites are selected without consideration of their relation to underlying waters. For this reason the location of new dump sites is subject to approval by the appropriate Regional Water Quality Board. Unfortunately there are many individually operated dump sites, including unused water wells, that have not yet come under the scrutiny of control agencies.

Solid wastes or refuse include garbage, rubbish, ashes, dead animals, etc. Approximately four pounds of refuse per person per day is produced in the United States (65). It follows that for California around 80,000,000 pounds of refuse must be disposed of each day. What is not burned or salvaged is dumped somewhere. Ravines, canyons, old excavations such as gravel pits, etc., usually are the location. Compaction and decomposition take place and with the introduction of water (rainfall, runoff, etc.) leaching occurs. Where near-anaerobic conditions exist, the decomposition of organic matter results in the formation of gases, principally methane, carbon dioxide, ammonia and hydrogen sulfide. Carbon dioxide when combined with water forms carbonic acid, which dissolves iron from tin cans and lime from calcereous deposits.

An interesting case recorded at Krefield, Germany is an example of the effects of refuse disposal on ground water. Refuse was dumped in an empty gravel pit from 1913 to 1929. Water was standing on the bottom of the pit. Deterioration in quality appeared in wells one mile downstream in 1923 and in wells five miles away four years later. Total hardness ranged between 600 and 900 parts per million compared with 225 parts per million in the native water. The maximum chloride measured was 263 parts per million as compared with 40 parts per million in the native water. No contamination with coliform bacteria took place. In wells nearest the dump the pollution lasted 18 years.

Similar incidents in California prompted the State and Regional Water Quality Control Boards to sponsor several studies concerning the leaching of dumps and their effect on ground water quality (31) (32) (33).

The disposal of household wastes on farms and ranches has seldom been a problem, but farmers have waste disposal problems quite similar to those in urban areas. Solid agricultural wastes include crop residues, dead animals and livestock manures.

Professor Samuel Hart, University of California at Davis, states that "... For every pound of food that gets to a store to be sold, between two and five pounds of crop residues are left in the field and packing shed...." (71). Most crop residues are combined with the soil as part of the normal farming practice. But when crop residues are piled or dumped, their effects are comparable to those of other dumps, although much less severe.

Of more serious consequence is the disposal of dead animals, particularly poultry because the random dead cow, horse or sheep is disposed of by scavengers or other means. Referring again to Professor Hart:

> " There is one significant and serious exception however. Large poultry farmers always have a sizable death loss of chickens. Poultrymen figure their laying flock mortality is about 1% per month--a 100,000 hen flock will average 35 dead chickens every day. Disposing of these birds is often quite a problem. One rather common solution is to dig a cesspool or pit--about 4 feet in diameter and 20 or 30 feet deep. This is covered with a slab with a 6-inch hole. Each day's dead birds are merely dropped in this hole. As you can well imagine, pollution of the underground waters can and probably often does occur." (71)

Some persons have used old water wells for this purpose. Mr. Fred Hanssler of Ramona, California at the public hearing on the preliminary edition of this bulletin, in San Diego, March 31, 1965, stated:

> " ... I know of instances in the poultry industry where abandoned water wells are used as disposal pits for poultry. That may or may not be dangerous, but certainly until somebody proves it to me differently I believe it is dangerous, that if this dead poultry is allowed to rot and go into water strata it is dangerous...."

From the standpoint of effect on ground water quality, the most significant agricultural waste is livestock manure. Professor Hart states:

> " ... Each pound of meat results in 8 to 25 pounds of manure being left on field or feedlot, each quart of milk is accompanied by two quarts of manure. Today we have beef feedlots of 5,000 to 30,000 animals confined on 20 to 100 acres. The farmer slopes the corral area so that when it rains his animals will not be standing in mire. Runoff picks up a large amount of manure making the water badly polluted, often many times as strong as domestic sewage...." (71)

The leachate from feed lots, pens, manure piles, manure lagoons, etc., contains salt and organic material in very heavy concentrations which, on percolating, certainly degrade underlying waters. Considerable effort is being made to resolve problems of manure management. In this regard, A. F. Lenain reported a particularly repulsive incident at Anaheim, California involving a well:

> "... Another well, upon being abandoned on a dairy site, was filled with dairy manure. This prompted an ordinance in the late 1950's by the City of Anaheim on the backfilling of wells...." (45)

<u>Sea Water</u>

In many ground water basins bordering the California coast and inland salt water bays, sea water has intruded into both unconfined and confined aquifers containing fresh water. Quite often, coastal areas subject to intrusion of sea water are underlain by more than one aquifer. Producing zones with good quality water that are physically separated from the intruded zone (or zones) will remain of good quality unless faulty wells, or other breaks in the restricting layer, permit the interchange of water. In several coastal areas where sea water has intruded and degraded fresh water, the degradation has migrated from one aquifer to another through defective wells.

Intrusion of sea water, caused by lowering of the elevation of the ground water table to a point below sea level, is due primarily to overdraft of these coastal ground water basins. This drop in ground water table reverses the natural seaward hydraulic gradient and enables the saline water to move landward into the ground water basin. Problems of sea water intrusion along the south coast of California in Ventura, Los Angeles, and Orange Counties are quite well known. The problem also occurs in parts of the San Francisco Bay area, around Monterey Bay, and in other smaller coastal ground water basins.

An example is an Orange County well which was perforated in a deeper aquifer and suddenly yielded water similar to sea water. The portion of the casing passing through the intruded upper aquifer had rusted. The difference in water levels between the two aquifers was 19 feet, favoring the transfer of water from the upper, intruded aquifer to the lower aquifer.

During the Department's investigation of salt water intrusion in Southern Alameda County (1957-60), out of 100 possible problem wells, 20 were allowing interchange of saline water between aquifers. In addition, 17 other wells were in poor condition. All 37 wells were eventually sealed or repaired under supervision of the Department (28).

The status of sea-water intrusion into ground water basins in California is summarized in Department of Water Resources Bulletin No. 63 (26). Additional data and information concerning intrusion in particular basins and areas are contained in various other departmental publications (27) (28) (30).

Deep-seated Waters

Deep-seated connate waters underlie fresh water-bearing aquifers in many of the ground water basins of California. The great Central Valley is a notable example. It can be said with a fair degree of certainty that the entire length of the valley, from the Redding Basin on the north to the Southern edge of the San Joaquin Valley, is underlain by waters of this type.

Such waters are generally confined under pressure by overlying impervious formations. Originally they were ocean waters or lake waters which were entrapped in the sediments at the time of deposition. The quality of these connate waters has undergone changes since the time of deposition. In some localized areas, saline connate waters may have been diluted by mixing with fresher waters, and the resulting waters may be of satisfactory mineral quality. Unless they are thoroughly diluted, however, most connate waters are saline and unsuitable for most uses.

Under some conditions, relatively deep-seated connate waters may migrate upward into bodies of fresh water through natural channels such as faults, or through permeable zones; or they may migrate upward into fresh waters as a result of heavy pumping draft and the accompanying reduction of the water levels in the overlying pumping zone. Saline connate waters can also invade fresh water aquifers directly through wells which extend into the underlying strata containing these saline waters.

A limited amount of highly mineralized water is derived from molten rock at considerable depth below the surface of the earth. Some of the "mineral" or "hot" springs in California contain waters of this type. Because such waters are so highly mineralized, they degrade the quality of fresh ground waters with which they come in contact.

Other Sources

In addition to degradation of ground water by those discussed above, degradation of water in individual wells can come from other sources.

These include: (1) drippage of pump lubricants (depths of oil up to 50 feet have been found floating on the water within the well casing), (2) introduction of water of undesirable quality during construction or repair of wells, and (3) entrance of small animals, insects or other foreign material into wells.

Water Well Construction Practices

In preparing the standards presented in this report, present water well construction and destruction practices were considered. These practices are not limited to construction features alone, but include existing regulations and the recommendations of various agencies, organizations, and individuals recognized as authorities on water supply and conservation, public health protection, and water well construction.

Construction

Water wells are constructed by a variety of methods in California. The method employed depends upon such factors as the occurrence and nature of ground water in the area, formations encountered, availability of materials and equipment, and quantity and quality of water desired. In relation to methods of construction, there are five fundamental classifications of water wells; drilled, dug, bored, driven, and jetted. Various handbooks and text books describe these methods of construction (40) (44) (54) (57) (67). The basic principles involved are presented in Appendix C.

It is estimated that about 95 percent of the water wells constructed in California by commercial drillers are drilled wells. The remaining five percent are installed by drillers who specialize in the construction of bored, driven, or jetted wells in their particular locale. Dug wells and some bored wells are constructed predominantly by individuals for their own use, or by businesses engaged in excavating, post hole digging, etc.

In a sense, all wells, except those that have been excavated by digging, are "drilled" wells; i.e., some mechanism for penetrating the earth other than a scoop or shovel was used in their construction. However, as commonly used, drilling refers to one or the other of two principal methods of construction or a variation of them. They are: (1) the cable tool method and (2) the rotary method. The most suitable drilling method (or variation) to use often depends on the physical properties of the formations to be penetrated. Under most conditions in California, either the cable tool or rotary method of drilling is satisfactory. All deep wells in the State are drilled wells.

To prevent the impairment of ground water quality by the entrance of foreign material, and of contaminated or other undesirable water into well casings, special attention should be given to certain aspects of water well construction. These include: (1) location of the well, (2) surface features of the well, (3) subsurface features of the well, (4) methods of well development and (5) disinfection. These features will not in themselves, preclude impairment to water quality. Their purpose is to merely prevent, either partially or completely, impairing agents from entering and mingling with the water in the well or aquifer. Invariably, it is poor location or the lack of some features, or inadequacies in their construction, that result in problems of ground water quality impairment. Details regarding these aspects of well construction are presented in Appendix D.

Maintenance and Reconstruction

As with any other type of constructed installation, maintenance and reconstruction of wells are important so far as their continued utility is concerned. It is reasonable to expect that eventually a well's productivity will decrease substantially. When this time comes depends on several factors. Some of these are directly related to maintenance whereas others, such as general lowering in the water table, involve extensive construction activity if production is to be restored to a level comparable to when the well was first constructed.

A principal cause of decreased productivity is clogging of the openings in the casing or screen or of the pore spaces in the water-bearing formation in the vicinity of the hole. This incrustation results from the deposition or accumulation of extraneous material in the openings or pore spaces. Incrustations are produced chemically as with the precipitation of carbonates (a hard water scale); by the development of slime (produced by iron bacteria for example); or by deposition of sloughing or suspended matter such as silt or clay. These incrustations can be removed with chemicals in conjunction with development methods that produce agitation. (The process is sometimes called "redevelopment"). A variety of chemicals are marketed for this purpose including muriatic acid (hydrochloric acid), sulfamic acid, chlorine in solution, polyphosphates (dispersing agents) and others. These agents should be used carefully and in accordance with instructions issued by the manufacturer so that the well will not be damaged. Where incrustation is unavoidable it can be minimized by early maintenance. Selection of the proper chemicals depends on determination of the type of incrustation.

Reconstruction may involve minor repairs, deepening, more extensive redevelopment than that described in the preceding paragraph, or replacement of casing or screen, all of which are handled by the methods and procedures described in Appendix C.

Well Abandonment and Destruction

Although the term "abandoned well" is almost universally used to describe a well that is no longer in use, and is used in this manner in the California Water Code, it is a vague term. It is generally agreed that whether or not a well is abandoned depends on the intent of the well's owner, a factor which plays an important part in the definition of the term. Thus, some wells are "temporarily abandoned" or left idle with the pump removed. In this instance, the owner intends to use the well again at some future date. Conversely, when the owner never intends to use the well again it should be destroyed.

However, a real problem exists in the case where the owner indicates his intent to again use a particular well and never does, nor does the succeeding owner or heir. Under these circumstances the well is technically, although perhaps not legally, "abandoned". Such wells are unquestionably the most troublesome, since, as so often happens, their existence is ignored or forgotten. Once forgotten, it is too late to take any corrective action; furthermore, as time goes by, there will be more and more wells which are no longer used.

An idle or "abandoned" well which is left open is recognized as a public hazard. Such a well also presents a potential threat to the quality of ground water even when properly covered. Open wells provide a channel for the flow of surface water into ground water, and easy access for small animals and insects (which invariably fall into the well and die, with the carcass decomposing), as well as other foreign material. In addition, casing eventually deteriorates and permits the movement of waters, formerly separated, from one aquifer to another. Where such interchange of waters must be avoided, the fact that there is no operating pump to remove a portion of the undesirable water makes the "abandoned" well an even more critical problem. Old wells, in which upper waters can actually be heard falling into the well, have been encountered a number of times in investigations of the department. Furthermore, there is no assurance that the random collapse of the walls of the hole will ever occur, or, if it does occur, that an adequate barrier to the transfer of water has been formed.

Consequently, if the owner intends to use the well again in the future, it should be kept in good repair. Conversely, if the well is to be destroyed, (as eventually every well must be, at the end of its useful life), it should be destroyed in such a manner that the quality of the ground water around it will not be impaired. "Destruction" means purposely filling the well with material in such a way that the well will not (1) produce water, (2) act as a conduit for the interchange of poor-and good-quality water, or (3) present a safety hazard.

Presumably, if a well is constructed properly to begin with, there would be little need for additional work on the well for many years, perhaps even to the time when the well is no longer useful.

The American Water Works Association states that:

> "The basic concept of proper sealing of abandoned wells is the restoration, as far as feasible, of the controlling geological conditions that existed before the well was constructed." [10]

This concept is almost universally endorsed [15] [67] [73]. Where unconfined ground water conditions exist, the sealing operation should prevent the vertical movement of surface, or shallow, subsurface waters to the water table through the original well opening or in the annular space outside of the casing. Under confined ground water conditions, the sealing operation should result in water being confined to the aquifers in which it occurs. This prevents loss of artesion pressure and provides protection against interchange. Each sealing problem should be considered as an individual case.

There have been a number methods devised for sealing wells, some of which, such as the careless filling of the well with trash, garbage, and the like, are more detrimental than if the well had been left completely open. However, there is only one sure way to close a well which is no longer to be used; this is to completely fill the well, including probable void spaces.

In addition to completely filling the well, most authorities recommend that: (1) the well be checked for obstructions prior to filling, (2) casing "liners" be removed if possible, (3) as much lining as possible be removed from dug and bored wells, (4) the upper portion of casing in all wells be removed, and (5) the upper portion of all wells be sealed with impervious material. They also recommend the use of cement grout, concrete, or clays with sealing properties similar to cement as the impervious material, and that such material be placed from the bottom up to assure a continuous seal and to avoid segregation or dilution of material. (For more details see references (15) (57) (67) (68).

Gravel envelope wells are especially difficult to seal, and several authorities recommend that to obtain an adequate seal, they be filled with cement or clay introduced under pressure and in sufficient quantity to fill the gravel envelope as well as the interior of the casing. Drillers in the State who undertake destruction of wells are evenly divided as to the use of cement grout or clay for sealing materials.

Legal Powers and Limitations of the State and Local Agencies With Respect to Ground Water and Water Wells

Although state laws regarding the licensing of water well drillers, the capping of artesian wells, and the protection of water quality, have existed for sometime, it was only during the past (1967) legislative session that a statute was enacted which authorizes the State to adopt minimum water well standards as a means for protecting the quality of ground water in critical areas if cities and counties fail to do so. This legislation, which establishes a procedure for the implementation by local governmental agencies (or the appropriate regional water quality control board) of standards developed under Section 231 of the California Water Code, is contained in Chapter 7 of Division 7 of the Water Code (Sections 13700-13806), added by Chapter 323, Statutes of 1967. A detailed discussion of existing state legislation is presented in Appendix D.

Twelve of California's 58 Counties have ordinances regulating the construction, abandonment, or destruction of water wells. They range in scope from simple endorsements of the "Kathy Fiscus Law" (Section 24400 of the Health and Safety Code, which requires the filling, covering, or fencing of excavations) to requirements covering construction features and materials. The content of these ordinances is summarized in Table 1. These ordinances are administered by the respective county health departments. In addition, several county health departments have standards which they apply to the construction of community water supply wells in systems under their jurisdiction. Notable among these are San Bernardino and San Diego

Counties. While it has been some time since they were polled, an estimated 10 percent of the cities in California also have such ordinances.

Clearly, the state and local governments have the power to enact additional laws and ordinances if, and where, necessary to protect ground water basins from pollution and contamination.

TABLE 1 [(a)]

SUMMARY OF ORDINANCES IN CALIFORNIA COUNTIES PERTAINING TO WATER WELLS

County	Ordi-Nance No.	Permit or Notice	Ordinance Covers: Construction: Location	Construction: Construction Features	Abandonment: Cover (Temporary)	Abandonment: De-Stroy	Abandonment: Sealing Requirement
Contra Costa	1189	P	R	R		O	O
Fresno	389				O	O	
	524[(b)]	N	O	O	O	O	
Los Angeles	7583[(c)]	P[(d)]	O	O		O	O
Mendocino	333	P	R	R			
Merced	275				O	O	
Riverside	340A	P					
Sacramento	508	P	O	O			O
San Francisco	659	P				R	
San Luis Obispo	9-905	P	R	R		R	R
San Mateo	1100	P	O	O,R	O		O
Santa Clara	NS						
	1203.12[(e)]		O	O		O	R
Tulare	385				O	O	

(a) Symbols used are:

P - Permit
N - Notice
R - Governed by regulations
O - Specific provisions in ordinance

(b) Applicable to individual domestic wells only.
(c) Not all provisions apply to all wells.
(d) Permit for reconstructed or converted wells.
(e) Applies to individual domestic wells and community water supply wells.

APPENDIX A

SUMMARY OF HEARINGS AND DIGEST OF COMMENTS RECEIVED ON PRELIMINARY AND INTERIM EDITIONS

APPENDIX A

SUMMARY OF HEARINGS AND DIGEST OF COMMENTS RECEIVED ON PRELIMINARY AND INTERIM EDITIONS

Where a bulletin is of general interest or its subject is one on which there can be a diversity of opinion, it is the policy of the Department of Water Resources' to issue the bulletin in preliminary form and solicit comments from all interested individuals and agencies and from the general public. The preliminary edition of this bulletin was released in December 1962 and comments were requested. Public meetings or hearings (although much less formal than the usual "hearing") were held in March and April 1965.

Legislation concerning water well standards was introduced in the Legislature on April 20, 1965 (Assembly Bill 2707), but subsequently on June 4, this portion of the bill was amended out, and pursuant to House Resolution 586 the subject matter was referred to the Assembly Interim Committee on Water for study. The Committee held two hearings (September 23, 1965 and September 28, 1966) and although attention was focused on this bulletin much of the time, it should be pointed out that the Committee hearings were independent of those described in this appendix.

An Interim Edition of the portion of the Bulletin containing the standards was issued in February 1967 and public meetings were held in May 1967.

A summary of the Department's hearings and a review of the comments (both oral and written) received are presented in this appendix. Transcripts of the hearings and copies of the written comments are available for inspection in the Department's file in Sacramento.

The Preliminary Edition

In 1965, six public meetings were held in conjunction with the

Department of Public Health to hear comments on the Preliminary Edition. The dates, locations, and attendance for these meetings are listed in Table 2.

TABLE 2

DATE, LOCATION AND ATTENDANCE AT HEARINGS

Date of Meeting	Location (City)	Number of Persons Attending*
March 18, 1965	San Jose	37
March 25, 1965	Fresno	46
March 30, 1965	Los Angeles	49
March 31, 1965	San Diego	14
April 6, 1965	Eureka	14
April 7, 1965	Redding	34
May 1, 1967	Los Angeles	48
May 8, 1967	Sacramento	53

* Exclusive of Personnel of Departments of Public Health and Water Resources.

The one hundred eighty-five attendees represented 144 individuals, businesses, and public agencies. Sixteen formal (written) statements were presented, and 59 persons commented informally (from notes or during the discussion).

In addition, written comments were received from 25 organizations; six during 1963 (the year following release of the Preliminary Edition) and the remaining 19 between March 1965 and August 1966.

Agencies and individuals who commented on the Preliminary Edition are listed in Table 3.

TABLE 3

ORGANIZATIONS COMMENTING
ON BULLETIN NO. 74

Preliminary Edition

Organization	Representative	Date of Comment	Type of Comment*	
Alameda County Water District	M. P. Whitfield	8/8/63		W
		3/18/65	O	
Ivan Alexander Well Drilling Anza	I. D. Alexander	3/31/65		W
American Water Works Association California Section	A. W. Jorgensen	3/30/65	O	W
Arcata Pump and Electric Co.	A. A. Piplorsi	4/6/65	O	
Associated Drilling Contractors Sacramento	E.E. Luhdorff, Jr.	3/18/65	O	W
Bakersfield Pump Co.	R. D. Ferguson	3/30/65	O	
Ballard & Foote Drilling Sebastopol	Robert Foote	3/18/65	O	W
Berkeley Pump Co.	Jack Milan	4/6/65	O	
C & N Pump & Well Co. Salinas	A. B. Burden	3/18/65	O	
City of Albany Department of Public Health	H. Van Coops, R.S.	3/22/65		W
City of Azusa	P. D. Foxworthy	3/30/65	O	
City of Fresno Department of Public Works	Jesse Robinson	3/25/65	O	
		3/31/65		W
City of Garden Grove	G. G. Oldham	3/31/65	O	
City of Huntington Beach	E. R. Stang	3/30/65	O	
City of Long Beach Department of Public Health	F. T. Higgins	3/30/65	O	
City of Los Angeles Department of Water and Power	E. B. Lowry	3/30/65	O	
		5/24/65		W
City of Oxnard Department of Water and Power	F. J. Schroeder	3/30/65	O	
City of Palo Alto Water Division	H. R. Remmel	3/18/65	O	
City of Pasadena Department of Water and Power	D. A. Blackburn	3/30/65	O	W
City of Sacramento				
Office of the City Engineer	E. A. Fairbairn	5/10/63		W
Division of Water and Sewers	R. W. Jones	3/9/65		W
City of San Leandro Assistant City Engineer	R. H. Ward	3/18/65	O	
City of Santa Ana Department of Public Works	W. D. Schraub	10/11/63		W
Clair Hill and Associates Redding	Mel Landis	4/7/65	O	

TABLE 3 (Cont'd)

ORGANIZATIONS COMMENTING
ON BULLETIN NO. 74

Preliminary Edition (Cont'd)

Organization	Representative	Date of Comment	Type of Comment*	
County of Alameda Department of Public Works	Stanley Saylor	3/18/65	O	W
County of Butte Department of Public Health	Howard Toussaint	4/7/65	O	
Counties of Humboldt-Del Norte Department of Public Health	John Lamont	4/6/65	O	
County of El Dorado Department of Public Health	H. N. Mozar, M.D.	4/7/65		W
County of Fresno Natural Resources Coordinator	M. C. Boyer	3/25/65		W
County of Los Angeles Department of Public Health	E. Schulenburg	3/30/65	O	
County of Orange Water District	Langdon Owen	3/30/65	O	
County of Riverside Department of Public Health	M. B. Hawkins	3/30/65	O	
County of Sacramento Department of Public Health	A. W. Mathis, M.D.	3/12/65		W
County of San Diego Department of Public Health	J. B. Askew, M.D.	2/15/63		W
	J. B. Askew, M.D.	3/17/65		W
	R. F. Bott	3/31/65	O	
County of Santa Clara Department of Public Health	M. Pearl	3/11/65		W
		3/18/65	O	
County of Shasta Department of Public Health	D. E. Watson	3/30/65		W
		4/7/65	O	
County of Stanislaus	J. Domecq	3/25/65	O	
County of Yolo Department of Public Health	Hugh Hart	4/7/65	O	
H. E. Crabtree Drilling Contractor	H. E. Crabtree	4/7/65	O	
DeLucchi Well & Pump Co. Hayward	R. S. Delucchi	3/18/65	O	
Di Giorgio Fruit Corporation	Ralph Swarts	3/25/65	O	
		3/31/65		
Diversified Exploration Co.	Mel Williams	3/25/65	O	
Eaton Drilling Co.	Eaton	4/7/65		W
W. W. Frame Selma	W. W. Frame	3/25/65	O	
Fresno County Farm Bureau and James Irrigation District	Carl Hobe	3/25/65	O	W
	Robert Kent	5/6/65		W
Fred W. Hanssler Ramona	F. W. Hanssler	3/31/65	O	

TABLE 3 (Cont'd)

ORGANIZATIONS COMMENTING
ON BULLETIN NO. 74

Preliminary Edition (Cont'd)

Organization	Representative	Date of Comment	Type of Comment*	
Hennings Bros. Drilling Co.	Bernard Hennings	3/25/65	O	
N. R. Jessee Drilling Contractor	N. R. Jessee	4/7/65	O	
Kaiser Steel Corporation Oakland	A. L. Collin	4/7/65	O	W
R. R. Kemp Kerman	R. R. Kemp	3/25/65	O	
Kern County Farm Bureau	Robert Wegis	4/5/65		W
Kirby-Schramm Pump & Supply	Otto Schramm	3/25/65	O	
Layne and Bowler Pump Co.	C. D. Bower	10/21/65		W
Los Angeles County Flood Control District	M. W. Ransom	4/20/65		W
Los Angeles Regional Water Quality Control Board	Linne Larson	3/30/65	O	
McKinleyville Drilling Co.	LeeRoy Redden	4/6/65	O	
Merced Irrigation District	K. R. McSwain	8/29/66		W
Modesto Irrigation District	C. D. Crawford	8/26/66		W
Montague Pipe and Steel Co.	Oscar Fisher	4/6/65	O	
Roscoe Moss Company Los Angeles	Roscoe Moss, Jr.	3/30/65	O	W
National Water Well Association	J. F. Guardino	3/30/65	O	
		4/7/65	O	W
Northern California Swimming Pool Association	Otto Burgmeier	4/6/65	O	
A. F. Peterson Consulting Geologist	A. F. Peterson	3/25/65	O	
Rassmussen Well & Pump Service Fresno	R. L. Rasmussen	3/25/65	O	
San Joaquin County Flood Control & Water Conservation District	Robert Clark	4/7/65	O	W
Santa Clara County Flood Control & Water Conservation District	L. C. Fowler	3/18/65	O	
Smith & Smith Inc.	E. F. Smith	3/25/65	O	
State of California State Water Rights Board	L. K. Hill	3/15/65		W
Tanko Well Drilling Sonora	Vincent Tanko	3/25/65	O	
C. A. Thompson Well Drilling Santa Rosa	C. A. Thompson	3/18/65	O	

TABLE 3 (Cont'd)

ORGANIZATIONS COMMENTING
ON BULLETIN NO. 74

Preliminary Edition (Cont'd)

Organization	Representative	Date of Comment	Type of Comment*	
Triangle T Ranch Inc.	H. Schulbach	3/25/65	O	
Tulare Lake Basin Water Storage District	S. M. Barnes	3/25/65	O	
Turlock Irrigation District	R. V. Meikle	8/26/66		W
United Water Conservation District	R. Farnsworth	3/30/65	O	W
United States Department of Agriculture Forest Service	K. W. Kennedy	3/10/65		W
United States Department of Health Education & Welfare, Public Health Service	Graham Walton	3/14/63		W
United States Department of the Interior, Bureau of Reclamation	T. P. Ahrens	11/14/63		W
United States Steel Corporation	J. M. Wagenet	4/21/65		W
Valley Equipment Company Redding	N. Christianson	4/7/65	O	
Westlands Water District	M. K. Strantz	3/25/65	O	
	R. M. Brody	4/10/65		W
Fred Williams Drilling Contractor	Fred Williams	4/7/65	O	
Glen A. Williams	G. A. Williams	4/7/65	O	
Lyle B. Williams	L. B. Williams	3/30/65	O	

Interim Edition**

Organization	Representative	Date of Comment	Type of Comment*	
Alameda County Flood Control and Water Conservation District	P. E. Lamferman	4/25		W
American Water Works Association California Section	L. R. Hanson	5/2		W
Associated Drilling Contractors Sacramento	E. E. Luhdorff, Jr.	5/8	O	W
		6/30		W
Ballard & Foote Drilling and Weeks Drilling & Pump Sebastopol	Robert Foote	6/22		W
B & W Incorporated	J. R. Solum	5/8		W
California Farm Bureau Federation	Ray Hunter	5/8	O	W
California State Grange	Herman Grabow	5/8	O	
Central Valley Pipe Co.	R. D. Sherman	5/8	O	
City of Alhambra Office of City Clerk	D. V. McKusick	4/13		W
City of Long Beach Water Dept.	H. C. Levy	5/1		W
City of Los Angeles Department of Water and Power	E. B. Lowry	5/1	O	W
	J. G. Cowan	5/3		W

TABLE 3 (Cont'd)

ORGANIZATIONS COMMENTING
ON BULLETIN NO. 74

Interim Edition** (Cont'd)

Organization	Representative	Date of Comment	Type of Comment*	
City of Santa Monica Department of Public Works	J. R. Patten	4/13		W
Clark Well Drilling Company	R. L. Clark	5/8	O	W
Corps of Engineers San Francisco District	G. P. Reilly	4/24		W
Counties of Sutter & Yuba Department of Public Health	V. S. Reichard, R.S.	4/25		W
County of Alameda Department of Public Health	J. C. Malcolm, M.D.	5/2		W
County of Butte Department of Public Health	H. J. Toussaint	5/1		W
County of Contra Costa Department of Public Health	G. W. Kent, M.D.	5/8		W
County of Lake Board of Supervisors	D. E. Coolahan, M.D.	5/5		W
County of Los Angeles Department of Public Health	H. F. Eich	5/1	O	
County of Mendocino Department of Public Health	D. C. Long, R.S.	4/11		W
County of Placer Department of Public Health	Jack Vrmeer	5/8	O	W
County of Riverside Department of Public Health	M. B. Hawkins	5/1	O	W
County of Sacramento Department of Public Health	R. L. Dills	5/8		W
County of San Bernardino Department of Public Health	J. H. Martin, R.S.	4/6		W
County of San Diego Department of Public Health	R. F. Bott	4/14		W
County of Santa Clara Department of Public Health	E. H. Pearl	5/4		W
County of Shasta Department of Public Health	D. E. Watson	4/7		W
County of Yolo Department of Public Health	H. G. Hart	5/8	O	
Di Giorgio Fruit Corporation	R. H. Swarts	5/1	O	
William G. Dunn Consulting Engineer	W. G. Dunn	5/8	O	
Fresno County Farm Bureau and James Irrigation District	Carl Hobe	5/8	O	W
Hennings Bros. Drilling Co.	Bernard Hennings	5/8	O	

TABLE 3 (Cont'd)

ORGANIZATIONS COMMENTING
ON BULLETIN NO. 74

Interim Edition** (Cont'd)

Organization	Representative	Date of Comment	Type of Comment*	
Kaiser Steel Corporation	A. L. Collin	5/8	O	W
Kings River Water Association	R. L. Kent	5/8	O	
Lahontan Regional Water Quality Control Board	J. T. Leggett	2/14		W
Merced Irrigation District	K. R. McSwain	5/8	O	W
Modesto Irrigation District	C. D. Crawford	5/8	O	W
Montague Pipe & Steel Co.	O. H. Fisher, Jr.	5/8	O	
Roscoe Moss Company Los Angeles	Roscoe Moss, Jr.	6/15		W
National Water Well Association	J. F. Guardino	5/8	O	W
Noack, Inc.	Walter Noack	5/8	O	
Nicholas H. Russo Co. San Jose	N. H. Russo	4/4		W
San Jose Water Works	N. J. Kendall	6/20		W
San Luis Obispo County Flood Control & Water Conservation District	R. H. Born	2/9		W
Shasta County University of California Agricultural Extension Service	R. H. Gripp	4/6		W
State of California Department of Conservation Division of Forestry	L. T. Peterson	5/5		W
State of California State Water Rights Board	L. K. Hill	2/27		W
State of Nevada Department of Conservation and Natural Resources	B. J. Vasey	2/17		W
Turlock Irrigation District	R. V. Meikle	4/19		W
United States Steel Corporation	George Tupac	5/1	O	
United Water Conservation District	W. P. Price, Jr.	2/17		W
Upper San Gabriel Valley Water Association	A. W. Jorgensen	5/1	O	
Westlands Water District	R. M. Brody	4/25		W

* O- Oral
W- Written
** All comments on interim edition dated 1967.

As might be expected, almost all comments pertained to either (1) the standards as published in the Preliminary Edition or (2) means for their implementation. A few chose to comment about technical points in other sections of the publication (for example, ground water quality conditions and methods of sealing). Consequently only those comments concerning the standards are included in this discussion.

The Interim Edition

From a complete review of all comments, the Department concluded that the standards as presented were too general and in need of elaboration. The Department further concluded along with the Department of Public Health, that a uniform set of standards (within the limits of practicability) for use by both departments could be produced. Accordingly, the standards were revised along these general lines:

1. A presentation resembling a model ordinance was chosen over the modified prose used in the preliminary edition. With this style there is less possibility of mistaking intent and most explanatory material and methods and procedures can be relegated to footnotes or appendixes.
2. Detailed provisions pertaining to community water supply wells were incorporated into the various sections of the standards (in the preliminary edition such provisions appeared in an appendix).

An Interim Edition of the standards was issued in February 1967, and two public hearings were held to hear comments relating to its content. The dates, location and attendance at these hearings are presented in Table 2.

The persons attending the hearings represented 82 organizations, both private and public. Written comments were also received from 31 organizations of which 22 were not represented at the two public meetings. Agencies and individuals who commented on the Interim Edition are listed in Table 3.

Summary and Discussion of Comments

While almost all commenters endorse the hypothesis that standards concerning the construction and destruction of wells are necessary in California, there is a diversity of opinion as to their applicability. Opinions range from that of the local health official who feels that all wells should be treated alike (and thus insure protection for one and all); to the agriculturalist who abhors restriction and can see no need for standards for his well since it is in no immediate or foreseeable danger of becoming polluted, contaminated, or a means for deteriorating his neighbor's supply. There is of course some validity in each point of view and these form the basis for compromise. Standards can be neither too rigid nor too ineffective.

Discussion of the comments received parallels the listing of the various sections in the standards published in this edition. For the reader's convenience, the section number (and title, if different) used in the Interim Edition appear in parenthesis following the present title.

Section 1. Definitions and Section 2. Application to Type Of Well. Comments on these sections can be placed in three categories. First, several observed there was a "gap" between the definitions of: (1) Community Water Supply Well, (2) Individual Domestic Well, and (3) Industrial Well, and that wells serving apartment houses, gas stations, and other commercial establishments were not covered. This oversight has been corrected.

Second, many commenters believe standards should be applied to exploratory holes, geophysical test holes, and a variety of excavations. The point of view that such excavations should be controlled as another means of ground water protection is appreciated. The Legislature defined the meaning of water well during the 1967 session (it is quoted in Section 1 of the Standards); it is clear that excavations other than those constructed for the purpose of extracting water from or injecting water to the underground are not included.

Third, a question on the incidental use of agricultural wells to supply domestic water was raised; i.e., such wells were to be categorized as individual domestic wells. The problem is, what constitutes incidental use? Anyone who has worked outdoors in the summer has, at one time or another, taken a drink of water that is being discharged from an irrigation well. While this is incidental use, it is far different from the farmer who gets his domestic water from his irrigation well year round. It is the Department's opinion that in the latter situation the well is a dual-purpose well. To remove any doubt as to the possibility of contamination, such a well should be constructed in accordance with standards for domestic wells or some provision should be made for treating the water. On the other hand, if such domestic use is made only during the heavy irrigation season, there is doubt as to the benefit to be derived from incorporating additional protective features in the construction of the well. We believe that the degree of incidental use is best determined by the enforcing agency.

Fourth, many agricultural people felt that wells "way off" from problem areas or from people should not conform to standards. On the other hand, it was frequently pointed out that what is agricultural land today becomes a subdivision tomorrow with the wells usually abandoned, and that agricultural wells are often converted to individual domestic wells or community water supply wells. Still others see various types of agricultural wells as special purpose wells which should be set apart, and exempt from all standards. It is the opinion of the Department of Water Resources that regardless of the use to which a well is put, the important factors are the geologic and ground water conditions encountered. It is these factors more than anything else which govern the standards that should be applied to a particular well.

A fifth point brought out by the Lake County Health Officer concerned application of the standards to infiltration galleries, "Ranney wells", etc., since they come under the purview of the definition of water well. Because it is impractical to apply the standards to these kinds of "wells", Section 3, "Exemption Due to Unusual Conditions", and Section 5, "Special Standards", were added to the standards.

Section 3. Exemption Due to Unusual Conditions, Section 4. Exclusions, and Section 5. Special Standards. A few comments were received concerning the use of the term "observation well" in Section 4. We believe the term adequately describes a well used for the purpose of making hydrologic observations. No coments were received on Sections 3 and 5

Section 6. Well Drillers. From the number of comments and questions asked, it is apparent that many are unfamiliar with the provisions of the Contractors License Law concerning exemptions.

Persons constructing or altering wells for their own use are exempt (Section 7026.3 Business and Professions Code). Authorized representatives of the United States Government, the State of California, incorporated towns, cities, counties, irrigation districts, or other political subdivisions are exempt (Section 7040) from licensing requirements.

Several instances of unlicensed "fly by night" drillers who did not follow accepted good drilling practices were cited. Local agencies as well as drillers brought out this point. There is strong feeling on the part of drillers that all wells should be constructed by licensed drillers. Many well drillers are of the opinion that the owner should share the responsibility or be entirely responsible. Others believe the driller ought to assume responsibility for following standards because unless the owner is doing his own work, he can't be expected to know what should be done.

Section 7. Reports. Comments on this section were few and dealt with the present provisions of the law. Some commenters learned for the first time that there was such a law even though it has been in effect since 1949. There were pros and cons on the desirability and reasons for the confidential nature of these reports. The Department wishes to reiterate that the required reports are available to any governmental agency and only for the purpose specified in the law, i.e., for the purpose of making studies.

Section 8. Well Location with Respect to Contaminants and Pollutants. Several agencies cited conflicts with Federal Housing Authority requirements and distances listed in the Uniform Plumbing Code. This issue was raised in connection with both editions and although a change was made in the Interim Edition, further clarification was apparently necessary. The distances listed in the two standards cited (Federal Housing Administration and Uniform Plumbing Code) apply only to individual domestic wells. Other agencies favor the establishment of longer distances, definition of adverse conditions, and specification of minimum lot size where individual domestic wells are concerned. The standards have been revised to eliminate conflict with other requirements for individual domestic wells. Requirements for community water supply wells have not been changed. In addition, the standards allow the enforcing agency considerable leeway in establishing requirements. The Placer County Health Department, for example, (if it is the enforcing agency) may specify 100 feet, rather than 50 feet, as the distance between a well and a septic tank in 99 of 100 cases if conditions warrant the increased distance. In such a case, the agency would still be acting within the scope and intent of all three publications. Community water supply wells are already the perogative of the State and local health departments.

Section 9. Sealing the Upper Annular Space. (formerly titled Sanitary Requirements). The subject of Section 9 remains one about which there is much debate. Agencies such as the Lahontan Regional Water Quality Control Board and the Health Departments of Sacramento, Santa Clara, and Riverside Counties, maintain that all wells be sealed. Agriculturally oriented agencies generally feel that no agricultural well need be sealed. However, most commenters are willing to concede that there are exceptions.

Increased probability of exposure to contamination or pollution because of location near existing and potential sources of impairment, coupled with proposed use of the water, are the controlling factors in establishing standards for sealing the upper annular space. Consequently, we believe that an agricultural well located miles from any source of impairment requires no seal. However, if the well is next to a pig-pen, or 50 feet from a cesspool, or penetrates a near surface formation containing highly mineralized waters, it makes good sense to install a seal. (Or an alternative solution is needed such as situating the pig-pen or the well somewhere else.) On the other hand, where a house well is involved, there should be no doubt as to the desirability of sealing regardless of location or conditions.

There is some disagreement over how deep the seal should extend. The Associated Drilling Contractors recommend 30 feet for all wells. Others call for lesser or greater depths, generally without specifying a value. The State Department of Public Health, Bureau of Sanitary Engineering, firmly believes that 50 feet is necessary for community water supply wells. The Department of Water Resources believes that the depths listed in Section 9 are adequate.

Other suggestions covered methods and procedures employed under various conditions. An example is a method used by the City of Los Angeles, Department of Water and Power for constructing their wells. We do not recommend any particular method so long as it accomplishes the objective. After consulting with the State Department of Public Health, under whose purview the Los Angeles wells fall, we believe the method advanced by the Los Angeles Department of Water and Power is satisfactory.

Section 10. Surface Construction Features (formerly part of Section 9). Several suggestions were offered regarding the design of concrete pump bases (slabs); some felt that all wells should have a pump base, whereas others felt no pump base or slab was needed under certain conditions. We have concluded that although a pump base is desirable and is beneficial to the structural stability of the well, it may not be necessary provided that the requirements of Sections 9 and 10 are fully complied with.

Section 11. Disinfection and Other Sanitary Requirements (formerly portion of Section 9). The suggestion at one of the 1965 hearings that all wells be disinfected produced considerable discussion at the time and a succeeding influx of written comment on the subject particularly by those whose chief interest is agricultural wells. To set the record straight, the Department of Water Resources has always maintained that it is not necessary to disinfect agricultural wells.

Section 12. Casing (formerly Section 10). Although of less importance to the protection of ground water than several other sections in these standards, this section received more discussion (but not as many comments) than any other section. Over 40 percent of the 1967 hearing time was spent discussing steel well casing. Eight of the 31 letters received in 1967 contained comment on well casing.

There are differences of opinion between steel producers, fabricators and drillers as to what constitutes acceptable steel casing. So much confusion surrounds this issue that a few moments of discussion can result in heated arguments. It is particularly disappointing that after ten years no attempt has been made by these industries to resolve the matter.

In the preliminary edition, suggested thicknesses for various diameters and depths of steel casing were listed in much the same manner as the Associated Drilling Contractors, the major steel producers, and many fabricators have done. However, this type of presentation has at least three disadvantages: (1) No consideration is given to the type of material. (2) The user, if bound to this approach, must change the thickness of casing at exactly the depth specified. For example, if the table called for 10-gage material above 100 feet and 8-gage material between 100 and 200 feet and a driller constructed a 105 foot well, he could be required to install 5 feet of 8-gage material instead of 105 feet of 10-gage casing. (3) No allowance is made for a reduction in diameter with material of the same thickness as the depth is increased as an alternative to changing to a thicker casing.

Consequently, another approach was taken in preparing the Interim Edition. The principal types of materials were specified and recommended thickness for these types for various diameters were presented in tabular form. Unfortunately all producers, fabricators and drillers misinterpreted the table as a comparison of the particular product they favor with the other types.

A third approach is to specify the material and recommend one minimum thickness irrespective of type. This approach is used in this edition.

The issue is not really resolved. The Department of Water Resources does not favor any particular steel product over another, particularly since there is insufficient evidence forthcoming to demonstrate that any should be be favored. On the other hand, there is no reason to penalize a product which appears to be satisfactory. The Department believes that elaborate testing on our part to prove or disprove claims is going beyond the intent of the legislation authorizing the development of standards. However, we do believe that industry-oriented organizations have a responsibility and an obligation to resolve this dilemma.

Section 13. Sealing-Off Strata (formerly Section 11). Comments were similar to those received for Section 9, to which the reader is referred.

Sections 14, 15, 16, 17, 18, and 19 (formerly Sections 12 through 17). Minor comments were made concerning Sections 14 and 15. No comments were received for Sections 17, 18 and 19.

The suggestion that Section 16, "Special Provisions for Large Diameter Shallow Wells" (formerly "Special Provisions for Dug Wells") be expanded to include bored wells was accepted.

Part III. Destruction of Wells (Sections 20 - 23) (formerly Part II). Comment on the destruction of wells covered two areas: general applicability and details of the requirements for destroying wells.

The Department of Water Resources maintains that as long as a well serves a useful purpose, or is maintained so that it could be used, it need not be destroyed. However, some believe that certain wells, regardless of condition, should be forever exempt from destruction. These are not really opposite views because those who take the latter view always attach a condition of use to their comment and in effect are reluctantly agreeing.

Our particular concern is for those wells that are indiscriminately abandoned and pose a threat to the public safety and the preservation of the ground water supplies of the State. We believe the owner of the well has a responsibility to demonstrate that the well is, or can be, used regardless of whether it is used next year or 45 years from now. If this is not done, there should be no alternative but to properly fill it up ("destroy" it). We believe our requirements for proper maintenance, i.e., keeping the well in a state of good repair, keeping it covered, keeping its location clearly visible, keeping its surroundings clean, are not unreasonable. Such measures are simply good housekeeping.

What constitutes useful purpose must receive reasonable interpretation. Keeping the well in reserve status, as a great many cities do, is a useful purpose; using the well as a place to dispose of dairy manure is not. Where doubt exists as to appropriate use, the burden of proof must fall on the one who intends to make that use.

Most other comments pertained to refinements of the specific requirements listed. Some were incorporated into the present edition; others, such as specifying the thickness of alternative layers of materials and inclusion of bridge-plugging as an alternative to complete filling of the well, were not. We have no values for the thickness of alternate layers nor is there any to be found in the literature reviewed in preparation of this report.

We are not convinced that bridge-plugging would be a successful alternative to filling. There is no assurance that the "bridge" formed would remain in place. With complete filling (with filler material most of the depth of well and impervious material at the top and at appropriate levels) there is a great deal more chance of success.

APPENDIX B

GENERAL OCCURRENCE OF
GROUND WATER IN CALIFORNIA

APPENDIX B

GENERAL OCCURRENCE OF GROUND WATER IN CALIFORNIA

California geology is complex with large numbers of rock types covering a great span of geologic time. Major geologic forces shaping the California landscape and affecting the occurrence and movement of its ground waters include faulting, folding, uplift, subsidence, volcanic activity, glaciation, weathering, deposition of sediments, and gravitational movements of the land surface. The occurrence of ground water in California is summarized in this Appendix.

Because of these complexities it is impossible to describe California's ground water geology in great detail. Accordingly, this Appendix presents such information only in summary form. For detailed information about geologic conditions in a particular area, the reader should refer to publications of the United States Geological Survey and the California Department of Conservation, Division of Mines and Geology. Information about ground water conditions will be found in publications of the California Department of Water Resources and the United States Geological Survey, Water Resources Division.

Water-bearing Materials

The properties of water-bearing materials depend, to a large extent, upon the geologic conditions under which they were deposited or formed. A brief discussion of the significant water-bearing materials occurring in California is presented in the following paragraphs.

Recent and Pleistocene Sediments

The Department of Water Resources has identified over 250 areas in California that are underlain by water-bearing sedimentary materials of Recent and Pleistocene age. These areas of Quaternary sediments are designated as ground water basins and range in size from that of the great Central Valley (about 17,800 square miles on the surface) to very small but locally significant valleys. These materials are permeable, ranging from moderate to high, have moderate to high specific yields, and contain about one billion acre-feet of ground water storage capacity. The sediments have great capacity to absorb, transmit and store large quantities of ground water. A large variety of water-bearing geologic materials are included in these Quaternary sediments, such as alluvial fan and flood plain deposits, lake deposits, nonmarine terrace deposits, lagoonal deposits, and marine deposits.

Alluvial deposits of continental origin are made up of materials that were laid down by streams as stream channel, flood plain, and alluvial fan deposit The permeability of these deposits is variable and depends upon the size of the particles, degree of sorting, amount of consolidation, and related items. Stream channel deposits are usually composed of sand, gravel, and boulders which were transported by streams and subsequently deposited in the channels. Flood plain deposits, usually finer-grained than stream channel deposits, are composed of cla silt, and sand. They were laid down adjacent to stream channels when the streams overflowed their banks, and often overlie older, coarse-grained stream channel deposits. Alluvial fan deposits occur where streams emerge from an upland area and debouch upon a valley or plain. The coarser-grained material, in general, is deposited at the upper portion of the fan, near the mouth of the canyon, and the finer-grained material progressively outward toward the lower portion, or toe, of the fan.

The largest bodies of alluvium in California are found in the two major valleys, the Sacramento and San Joaquin Valleys. Tremendous quantities of ground water are stored in and extracted from these alluvial deposits. An estimated 60 percent of the gross storage capacity of the ground water basins in California is contained in the two valleys alone, and approximately 75 percent of all ground water used in California is pumped from them.

In the central portions of valleys, alluvial sediments often merge into, and are interbedded with, relatively fine-grained lake deposits. Sediments deposited in lakes are generally finer-grained and more homogeneous than those deposited as alluvium. They characteristically consist of clay, silt, and fine-grained sand. However, coarser materials may occur in places. Permeability of lake sediments is usually low. Consequently, they are generally poor water-producing deposits. Extensive lake deposits are found in the Modoc Plateau area of northeastern California. In this region, thick bodies of lake sediments occur in isolated basins surrounded by volcanic rocks. In arid or semiarid regions fine-grained lake sediments are deposited in playa lakes, which are broad, shallow, intermittent temporary lakes situated in low, flat portions of valleys. Such lakes generally have no outlets; and, when inflow ceases, evaporation of the water leaves a residue of salts incrusted upon the surface of the lake and in mud cracks. Playa lake sediments often are interbedded with alluvial deposits in areas of California where arid climates existed in the past. The Alkali Lakes and Honey Lake in northeastern California, and Searles, Rogers, and Bristol Lakes in the Mojave Desert are examples of playa lakes.

Along the coast of California, alluvial sediments in the valley areas interfinger with relatively fine-grained lagoonal deposits and moderately coarse-grained shallow water marine sediments. Lagoonal deposits, which were deposited in quiet bodies of brackish or saline water, consist of relatively fine-grained materials. Permeability of lagoonal deposits is generally low. Marine sediments deposited in near-shore areas of the coast consist of sand, gravel, silt, and clay. Permeability of these marine deposits is generally greater than that of the lagoonal deposits. For example, the marine deposited Silverado water-bearing zone of Pleistocene age in Los Angeles County contains extensive beds of sand and gravel which are as permeable as many of the inland coarse-grained alluvial sediments.

Older Quaternary and Late Tertiary Sediments

Flanking and underlying some of the extensive valley fill and coastal areas are extensive bodies of continental and marine sediments of Plio-Pleistocene age. These deposits are generally not as permeable as the unconsolidated Quaternary sediments. With the passage of time since their deposition, the percentage of voids for storage of water has been reduced by compaction due to the weight of overlying materials. Weathering has developed widespread clay pans and hard pans which restrict the vertical movement of water, and uplift, folding, and faulting have further restricted the vertical and lateral movement of ground water and in some areas has reduced the permeability. Despite their reduced water storage and transmissibility characteristics, these older sediments such as the Santa Clara formation, Livermore gravels and Paso Robles formation are significant water-bearing materials in California in that they function as important recharge areas to the basin and as areas of potential ground water development.

In addition to the extensive bodies of older Plio-Pleistocene sediments which flank and underlie the valley-fill areas, small quantities of ground water occur in isolated areas such as: the uplifted, dissected and thin discontinuous marine terrace deposits which occur in the coastal areas; the isolated glacial deposits in the Sierra Nevada and North Coast Ranges; and isolated bodies of residuum from crystalline rock largely in San Diego County. The occurrence of water in these rocks is extremely variable, primarily due to their heterogeneous nature, generally low permeability, and thinness of section.

Volcanic Rocks

The water-bearing properties of volcanic rocks are highly variable, depending on degree of jointing, fracturing, faulting, weathering, presence of lava tubes, and character of interbedded materials such as sand and gravel, and scoria. Where volcanic rocks are highly fractured and jointed such as the Recent and Pleistocene basalts in the Modoc Plateau and in other areas of northeastern and northcentral California, appreciable quantities of ground water can be stored in and moved through vertical and horizontal openings. Additional quantities of ground water can be stored in the volcanics over the amount contained in joints and fractures if lava tubes are present as in the Modoc Plateau and Cascade Range, if scoria and gravel beds are interbedded as in the Bishop-Lone Pine area in Inyo County, or if tuffs and sandy tuffs are present as in the Sonoma volcanics in Napa and Sonoma Counties where water is contained in the intergranular spaces like sandstones.

Nonwater-bearing Rocks

Rocks considered to be essentially nonwater-bearing include all rock types which have negligible primary porosity and permeability. Rock types would include broad categories such as: granitic (granite, diorite, gabbro); metamorphic (slate, schist, gneiss, amphibolite, quartzite, marble, serpentine); sedimentary (shale, sandstone, limestone, dolomite); and volcanic (basalt, rhyolite, tuff and agglomerate).

Where these rocks have developed secondary porosity and permeability due to jointing, fracturing, folding, faulting or weathering, small quantities of ground water may be stored in and moved through the rock mass. In general, yields to wells is quite limited. The nonwater-bearing rocks occupy a large percentage of the surface area of the State, principally in the mountainous areas; and they underlie all water-bearing rocks at depth.

Some of the sedimentary rocks classified as nonwater-bearing were deposited in ancient seas, and they still contain saline water. In some areas, primary or secondary permeability may be sufficiently high to allow movement of the saline water through the rock mass; and under certain ground water conditions of heavy pumping with changes in hydraulic gradients, migration of these connate waters may cause impairment of the quality of water in overlying or adjacent water-bearing materials.

Ground Water in California Hydrographic Areas

Ground water in California occurs in seven major hydrographic areas (Figure 3). Circumstances in each area are described in the following paragraphs.

North Coastal Area

Area underlain by very old igneous, metamorphic and sedimentary rocks, the Franciscan assemblage of sandstone, shale and serpentine, and some Tertiary volcanic flows. The only important ground water supplies are those of basins that contain valley-fill sediments. Ground water occurs in 18 alluvial-filled valleys, with an estimated gross storage capacity of about 2,100,000 acre-feet, or less than 1 percent of the total estimated gross ground water storage capacity in California.

San Francisco Bay Area

Area underlain largely by Tertiary sedimentary and volcanic rocks with some outcrops of older Franciscan assemblage rocks. Recent and Pleistocene alluvium, the Plio-Pleistocene Santa Clara formation and Livermore gravels, and the Pliocene Sonoma volcanics are important ground water storage areas. Ground water occurs in 11 alluvial-filled valleys, with an estimated gross storage capacity of about 3,000,000 acre-feet, or less than 1 percent of the total estimated gross ground water storage capacity in California.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

FIGURE 3

MAJOR HYDROGRAPHIC AREAS OF CALIFORNIA

Central Coastal Area

Area underlain largely by Tertiary sedimentary rocks with some outcrops of older igneous and metamorphic rocks and the Franciscan assemblage of rocks. Recent and Pleistocene alluvium, and the Plio-Pleistocene Paso Robles formation are important ground water storage areas. Ground water occurs in 19 alluvial-filled valleys, with an estimated gross storage capacity of about 14,000,000 acre-feet, or about 1.5 percent of the total estimated gross ground water storage capacity in California.

South Coastal Area

Area underlain largely by Tertiary sedimentary rocks and some older metamorphic rocks in the northern and central portions, and by very old granitic and metamorphic rocks in the southern portion. Quaternary alluvium and marine sediments deposited in geologically recent structural basins are important ground water storage areas in Ventura, Los Angeles and Orange Counties. In San Diego County, alluvial basins are smaller and shallower, having developed in geologic stable blocks. Ground water occurs in 43 alluvial-filled valleys, with an estimated gross storage capacity of about 57,000,000 acre-feet, or about 6 percent of the total estimated gross ground water storage capacity in California.

Central Valley Area

Area underlain by an extensive and thick layer of Tertiary and Quaternary sedimentary rocks, flanked on the east by very old igneous and metamorphic rocks in the Sierra Nevada, and on the west by Tertiary and older sedimentary rocks in the Coast Ranges. The alluviated Central Valley (Sacramento and San Joaquin Valleys) is the largest, most extensively and intensively developed ground water reservoir of any area of comparable size in the United States. Ground water in the entire drainage area of the Great Valley occurs in 29 alluvial-filled valleys with an estimated gross storage capacity of about 608,000,000 acre-feet, or about 60 percent of the total estimated gross gound water storage capacity in California.

Lahontan Area

Area underlain by very old igneous and metamorphic rocks comprising extensive mountain ranges, alternating with desert basins filled with Quaternary and Tertiary sedimentary deposits. Recent and Pleistocene alluvium and lake bed sediments, glacial moraines, and permeable volcanic rocks are important ground water storage areas. Ground water occurs in 58 alluvial-filled valleys, with an estimated gross storage capacity of about 148,000,000 acre-feet, or about 15 percent of the total estimated gross ground water storage capacity in California.

Colorado Desert Area

Area underlain by very old igneous and metamorphic rocks comprising extensive mountain ranges, alternating with desert basins filled with Quaternary and Tertiary sedimentary deposits. Recent and Pleistocene alluvium and lake bed sediments are important ground water storage areas. Ground water occurs in 45 alluvial-filled valleys, with an estimated gross storage capacity of about 135,000,000 acre-feet, or about 14 percent of the total estimated gross ground water storage capacity in California.

APPENDIX C

WATER WELL CONSTRUCTION METHODS AND FEATURES

APPENDIX C

WATER WELL CONSTRUCTION METHODS AND FEATURES

Well Construction Methods

Basically, a water well is constructed by excavating a hole in the earth's crust and lining the opening with an appropriate material so that the wall of the hole will not collapse. The well is then made operative by placing a mechanism inside the lining which lifts water to the surface of the ground, i.e., the pump. However, there are a number of structural and geological factors which must be recognized and dealt with before a well becomes operative.

Although wells are usually thought of as being constructed vertical to the plane of the earth's surface, there are, however, instances where wells have been constructed horizontally into the face of hills and mountains. Horizontal wells, generally of small diameter, have been installed for a number of years to assist in the stabilization of slopes in highway and railroad cuts, and occasionally they have been drilled to supply small quantities of water for domestic use and stock watering in mountainous areas.

The principal types of water wells are: drilled, dug, bored, driven, and jetted. For more details concerning these methods of construction see references (16, 39, 40, 44, 48, 54, 57, 58, 61, 70, 75).

Drilled Wells

The cable tool or percussion method of drilling is perhaps the oldest known method of well construction which does not involve digging. Its invention is attributed to the Chinese and dates back to the time of Confucius (600 B.C.)[40]. The method employs a "string of tools" suspended from a cable. A heavy bit on the end of the cable is alternately raised and dropped, thus breaking (or loosening) and crushing material at the bottom of the hole into small fragments. The reciprocating motion of the drilling tools operating in water mixes the loosened material into a "sludge" This sludge is removed from the hole periodically by a scow, bailer, or sand pump. Normally, the casing is forced (by hydraulic jacks) or driven down as the drilling progresses.

An innovation of this method developed in California around 1890, and which bears its name, is the California stovepipe method. A heavy mud scow is used as the drill bit as well as the bailer. Short lengths (4 feet) of steel casing composed of two layers of tubing fitted tightly over one another so that the outside section overlaps the inside section by one-half its length are used. The butted joints are staggered every 2 feet, hence the name "stovepipe". The short lengths of casing satisfy the stroke of the hydraulic jacks used in this method. The California stovepipe method of cable tool drilling has undergone modification since it was first developed. Cable tool drill hole diameters usually range between 4 and 18 inches although larger diameter holes have been drilled by this method.

The rotary method, as its name implies, is based on rotation of the cutting tool or bit coupled with the application of bit pressure against the material being cut. As drilling proceeds, water containing mud additives is usually circulated through the drill pipe and out through an opening in the bit. The mud-laden fluid then rises to the surface through the space between the drill pipe and the walls of the hole carrying the drill cuttings from the hole. When water wells are drilled by the rotary method, it is usually not necessary to install casing until drilling is completed because the mud-laden fluid forms a coating on the walls of the hole, which temporarily prevents caving. Drill hole diameters usually range from 4 to 24 inches.

Reverse-circulation rotary drilling, which is a variation of the conventional rotary method, was developed 40 years ago. However, commercial rigs, designed for this purpose, have been available only for about 20 years. In reverse-circulation rotary drilling, mud additives are seldom use. In this procedure, drilling fluid is circulated down the well and up through the drill pipe reverse to the direction used in the conventional rotary method. This method is particularly adapted to the drilling of large diameter wells, ranging from 14 to as much as 60 inches. Because of the size of the hole and the large volume of excavated material, a limitation on the method is that a substantial supply of water must be available. As originally developed, reverse circulation required the use of a vacuum system to maintain circulation, and, because of this, the practical drilling depth was restricted to around 400 feet. However, the introduction of compressed air as a means for circulating the drilling fluid has made drilling depths up to 1,500 feet possible.

Air rotary drilling (frequently called the "down-the-hole-hammer" method, "bottom-hole" method, or down-the-hole air percussion drilling) is the newest method used for constructing water wells. In this method compressed air provides the means for removing the cuttings from the hole and, at the option of the driller, serves as the source of drilling power. The air moving at a high velocity blows the cuttings up and out of the hole. Air as the circulating fluid is used primarily for drilling in consolidated (rock) materials. Consequently, the drilling rigs must be equipped to use mud for drilling through loose or "caving" materials such as overburdens.

By replacing the usual drilling bit with a tool that is essentially a pneumatic hammer and bit, it is possible to combine the percussive effect of cable tool drilling with the rotating action of rotary drilling. This down-the-hole-hammer pulverizes the material being cut. Further, the rate of penetration in rock is faster than other methods and with other types of tools. However, large diameter bits are not yet practical and where hammers are used, well diameters are restricted to 9 inches and less. The depth of drilling depends on capabilities of the air compressor being used and is usually no deeper than 500 feet. However, in experiments the method has been used at greater depths.

Dug, Bored, Driven, and Jetted Wells

Dug wells are excavated with hand tools such as a pick and shovel, or with mechanical equipment such as a clamshell bucket. To prevent caving, this type of well is usually "curbed", or cased during construction or immediately after the excavation is completed. Curbing usually consists of concrete, brick, metal, or wood. Dug wells are generally larger in diameter than most drilled wells seldom less than 2 feet, and are commonly from 3 to 5 feet in diameter. Dug wells are seldom constructed to any appreciable depth below the water table because of difficulties encountered in digging and curbing. However, shafts of considerable depth have been excavated. At the March 30, 1965, hearing on the preliminary edition of this bulletin, Mr. Duncan A. Blackburn, Chief Engineer, City of Pasadena Water Department, reported that his agency had dug well shafts up to 180 feet deep. The bottoms of these shafts were above the water table and were originally timber lined but later concrete lined. Casing was sunk below the bottom of the shaft.

The radial well, or collector well -- commonly called a Ranney well -- is a unique innovation of the dug well. It consists of a reinforced concrete shaf or caisson, from which horizontal intake pipes and screens project radially. The concrete caisson is about 15 feet in diameter, and the intake pipes, which are drilledor jacked hydraulically into the formation through prepositioned portholes in the caisson, are usually 6 or 8 inches in diameter[54]. The length of the individual radial pipes and screens varies from 100 to 450 feet depending on water bearing properties of the materials penetrated.

Radial wells are generally located near rivers, with the intake screens drawing primarily on the water infiltrating from the river. Installations on this type in California are located in or near the cities of Arcata, Crescent City, Sacramento, and Santa Rosa[49]. In addition, a radial collector well is situated in San Francisco and provides filtered sea water for Steinhart Aquarium.

Bored wells are constructed with hand-operated or power-driven augers. Although hand-augering obviously has extremely limited application, boring with power-driven augers has its place in the water well construction industry. There are two methods of well boring: one is called "rotary bucket drilling" or "auger bucket drilling", and the other employs the continuous-flight, or spiral, auger. Rotary bucket drilling is done by rotating a cylindrical bucket with auger blades on the bottom until it is filled with excavated material. The auger is then removed from the hole and emptied. This process is repeated until the desired depth is reached. This method is best applied in locations where formations will stand until the hole is completed and cased, or where temporary casing can be installed while boring at a smaller diameter continues. Diameters range up to 48 inches.

In continuous-flight augering the cuttings are pushed out of the hole as the auger is rotated into the earth; the auger need not be removed each time it is filled. Because the small diameters (usually 4 or 6 inches) restrict the use of temporary casing, this method is limited to formations that will stand without caving. Furthermore, when saturated sand is encountered, the auger flight cannot push out the material (which is a fluid), and further drilling is useless.

Boring is often used where small quantities of water are desired, and where water can be obtained at relatively shallow (under 100 feet) depths. However, small diameter wells have been sunk several hundred feet by boring.

Driven wells are normally constructed by driving a series of pipe sections into water-bearing materials. A pointed screen, or "drive point", is fitted to the end of the first pipe section to facilitate driving and to permit entrance of water into the pipe. The pipe is driven into the ground by sledge, maul, or power-driven hammer. After the initial section has been driven, succeeding sections are jointed and driven until the desired depth is reached, or until further progress is prevented by resistance of the formations. Pipe diameters are commonly 1-1/2 to 3 inches, but may range up to 8 inches. Depth of driven wells is limited by the properties of the water-bearing materials encountered and by the fact that the small diameter pipes preclude the use of large-capacity pumps. Common depths are 30 to 50 feet.

Jetted wells are constructed by the jet-percussion method, which involve the erosive action of a jet of water. Water is fed under pressure through a hollow drill pipe and drill bit against the bottom of the hole. As the jet loosen the material, the cuttings are carried out the top of the hole by the water rising in the hole. While jetting is taking place, the bit and drill pipe are raised and dropped in short strokes to break up the material as in cable tool drilling.

Casing is usually sunk (by driving) as the drilling proceeds, following closely behind the drill bit. Usually, after the casing has reached the desired depth, the well pipe with a well screen attached is inserted in the driven casing and lowered into the well. The casing is frequently pulled, leaving the well screen and pipe in the ground ready for use. Although larger and deeper wells hav been installed by jetting, the present use is limited to wells under 4 inches in diameter and less than 200 feet in depth.

Gravel-packed wells

A special type of well known as the gravel-packed or gravel-envelope well is frequently constructed in California. Gravel is placed in the annular space (the space between the well casing and the wall of the drilled hole), thus enclosing the casing in an "envelope" of gravel. Under current practice, the gravel envelope may extend through a single aquifer, through several aquifers, or through the entire length of the well. This type of well is constructed to (1) increase the effective diameter of the well, (2) prevent fine-grained sand from entering the well, (3) protect the well from the caving of surrounding formations, and (4) increase the yield of the well by allowing numerous thin aquifers to produce water. Gravel-packed wells may be constructed by either the rotary or cable tool method although the rotary method is most often used. Information derived from logs submitted by drillers indicates that about 70 percent of the gravel-packed drilled wells in California are constructed by the rotary method.

Construction Features Related to Protection of Ground Water Quality

Each pertinent feature of well construction, and its relation to the protection of ground water quality, is described in the following paragraphs. Where necessary, summary statements of existing practices, and recommendations are included. However, these descriptions do not cover all details of well construction or enumerate the variety of construction methods that can be used in each instance.

A number of the features discussed pertain primarily to the health aspects of quality protection, and others pertain to prevention of chemical impairment.

Well Location

The location of the well is the first feature to be considered when planning the actual facility. Authorities in the field of water supply and sanitation generally agree that water wells should be located a "safe" distance from potential sources of contamination or pollution. They also recognize that many local factors must be considered in determining safe distance. Such determination involves evaluation of (1) the character and location of the sources of potential contamination or pollution, (2) permeability of the geologic materials between the ground surface and the water-producing aquifer, (3) depth to ground water and its direction of movement, (4) physical character of the water-bearing materials, and (5) the effect of well pumping on the direction of ground water movement.

Greater distances from sources of contamination or pollution are requir in areas where permeable materials directly overlie ground waters than in areas where there is clay or other materials of low permeability. Wells should be located up the ground water gradient from sources of contamination so that any contaminating material that reaches the water will be carried away from the well. Another consideration is the possible local reversal of the areal ground water gradient in the vicinity of a well due to pumping. When water is withdrawn from a well, a drawdown cone of depression is formed in the water surface surrounding the well; and ground water in the area of this cone flows toward the well. Figure 4 illustrates the effect of reversal of ground water gradient when a well is located too close to a contaminant.

The Federal Housing Administration (FHA) and the United States Public Health Service (USPHS) have formulated recommendations regarding minimum distance between water wells and sources of contamination or pollution. These recommendations are listed in Table 4.

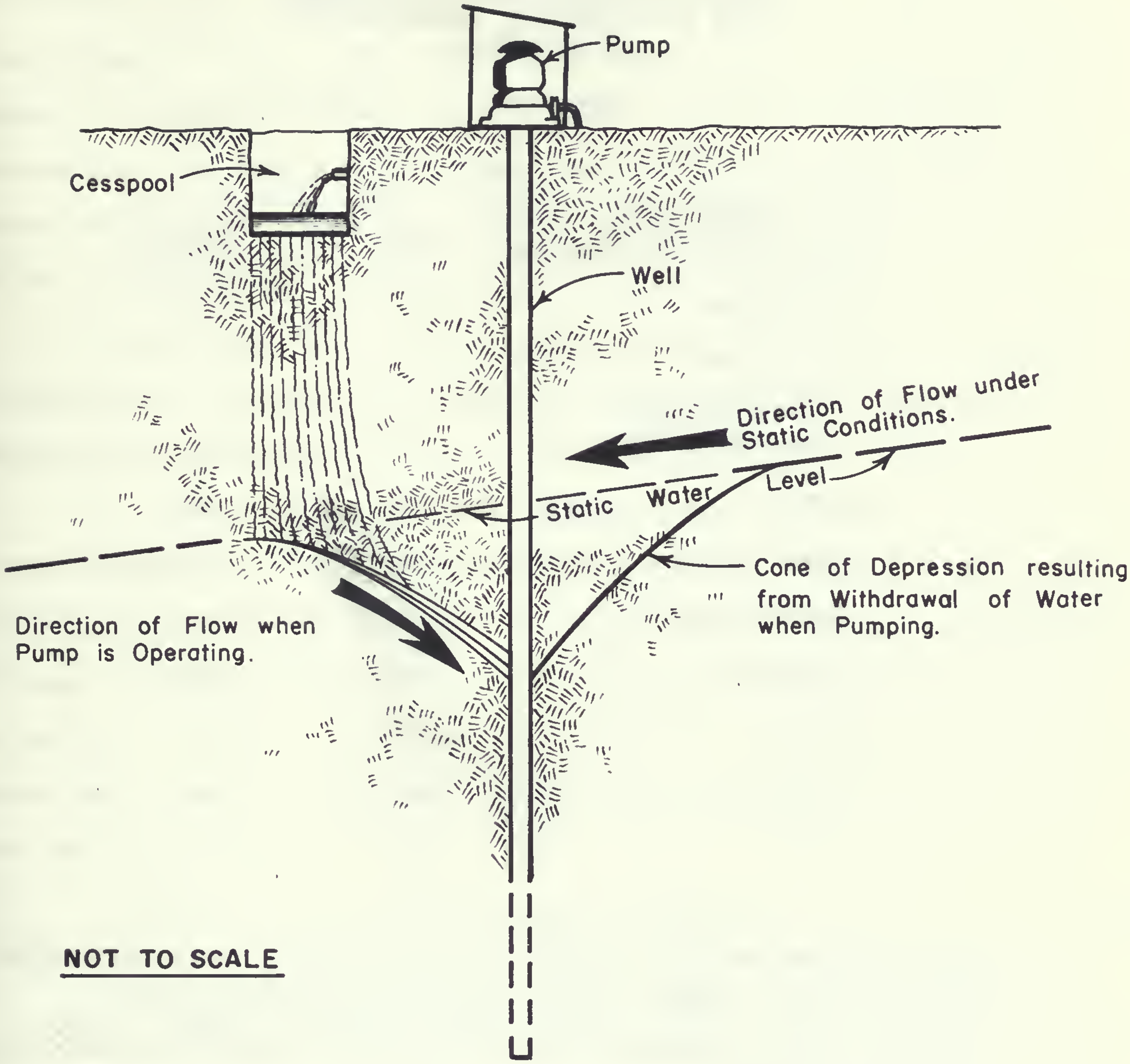

Figure 4

EFFECT OF REVERSAL OF GROUND WATER GRADIENT NEAR A WELL DUE TO PUMPING

TABLE 4

MINIMUM RECOMMENDED DISTANCE BETWEEN
WELLS AND SOURCES OF CONTAMINATION
OR POLLUTION

(In feet)

Sources of Contamination or Pollution	Agency FHA[a]	USPHS[b]
Septic Tank	50	50
Sewer Lines		
With Permanent Watertight Joints	10	10
Other	50	50
Sewage Disposal Field	100[c]	100
Absorption Bed	100[c]	---
Seepage Pit	100[c]	100
Drywell	50	50
Cesspool	---	150
Other	[d]	---

(a) Data from reference (38). Federal Housing Authority also requires that wells be located at least 10 feet from property lines.
(b) Data from reference (67). "The distances given are suggested values to be used as a guide. For specific recommendations contact the State or local health agency."
(c) "The horizontal separation between the sewage absorption system and the well may be reduced to 50 feet, only when the surface soil or subsoil receiving the sewage is effectively separated from the water supply formation by an extensive, continuous impervious strata of clay, hardpan, rock, etc. Also the well construction shall be such as to exclude surface water and sewage as effectively as did the undisturbed overlying impervious formation."
(d) "Recommendation of Health Authority."

These agencies consider that their recommended distances are generally safe where the upper formations are dry and not more porous than sand, and that these distances should be increased in areas where geologic and other conditions appear to be unfavorable with respect to preventing ground water contamination. Conversely, lesser distances may be safe where favorable subsurface conditions exist, or where special means of protection, particularly in construction of the well, are provided.

Results of the well drillers' questionnaire indicate that in California in actual practice there is considerable variation in distances between possible sources of contamination and location of the well drilled.

In addition to proximity to contaminants that may enter the well a short distance below the surface of the ground, water that might enter the well at the top must be considered. Such water as runoff from rainfall, agricultural drainage, wash waters and the like, readily transport contaminants or pollutants and may flow into wells. It follows then that the well should be located and constructed so that the top is above potential flooding and the drainage is away from the top of the well.

Surface Features

The construction features of the surface portion of water wells are equally as important as the deeper subsurface portions. This is especially true for wells which supply water for human consumption, since such features are more closely associated with prevention of contamination and pollution, primarily bacterial contamination, of the water produced from the well. The surface features are particularly important in very shallow wells. According to most authorities shallow wells are more frequently contaminated by material from the surface.

The various surface features of a well installation and their significance are discussed in the following paragraphs. Figure 5 depicts typical surface features of wells.

<u>Openings into Wells at the Surface</u>. Where a well contacts the ground surface, there are several openings that should be sealed or so constructed that surface water and foreign matter are prevented from entering (Figure 5). These openings are (1) where the casing and pump meet, (2) where holes which provide access to the well are installed (3) where the discharge pipe connects to the pump, and (4) where the annular space, i.e., the space between the casing and the side of the hole, is at the surface. The subsurface portion of the annular space is considered under the heading "Subsurface Features" (page 119).

The space between the pump head and pump base (slab), or between the pump head and casing, is the most common point of entry for deleterious materials. This space can be sealed by a gasket or by grouting. In the absence of a base, a device known as a sanitary well seal, or cap, is fastened over the top of the casing and around the pump column. All holes in the pump head that lead into the casing which are not access openings should be tightly closed. If pumps are offset from the well casing, the opening between the well casing and the pump column should be closed by a sanitary well seal or cap. The latter is also applicable where submersible pumps are used.

Access openings into the well casing are included during construction of a well, for sounding water levels, for air release, or for any other purpose necessary to properly maintain or operate the installation. Access openings should be protected against entry of contaminating materials by caps, screens, down-turned "U" bends, or other suitable means. These openings should be rendered watertight and should terminate above floodwater levels. Information obtained from studies conducted throughout the State by the Department of Water Resources indicates that most access openings are not protected against entrance of surface water or other foreign material.

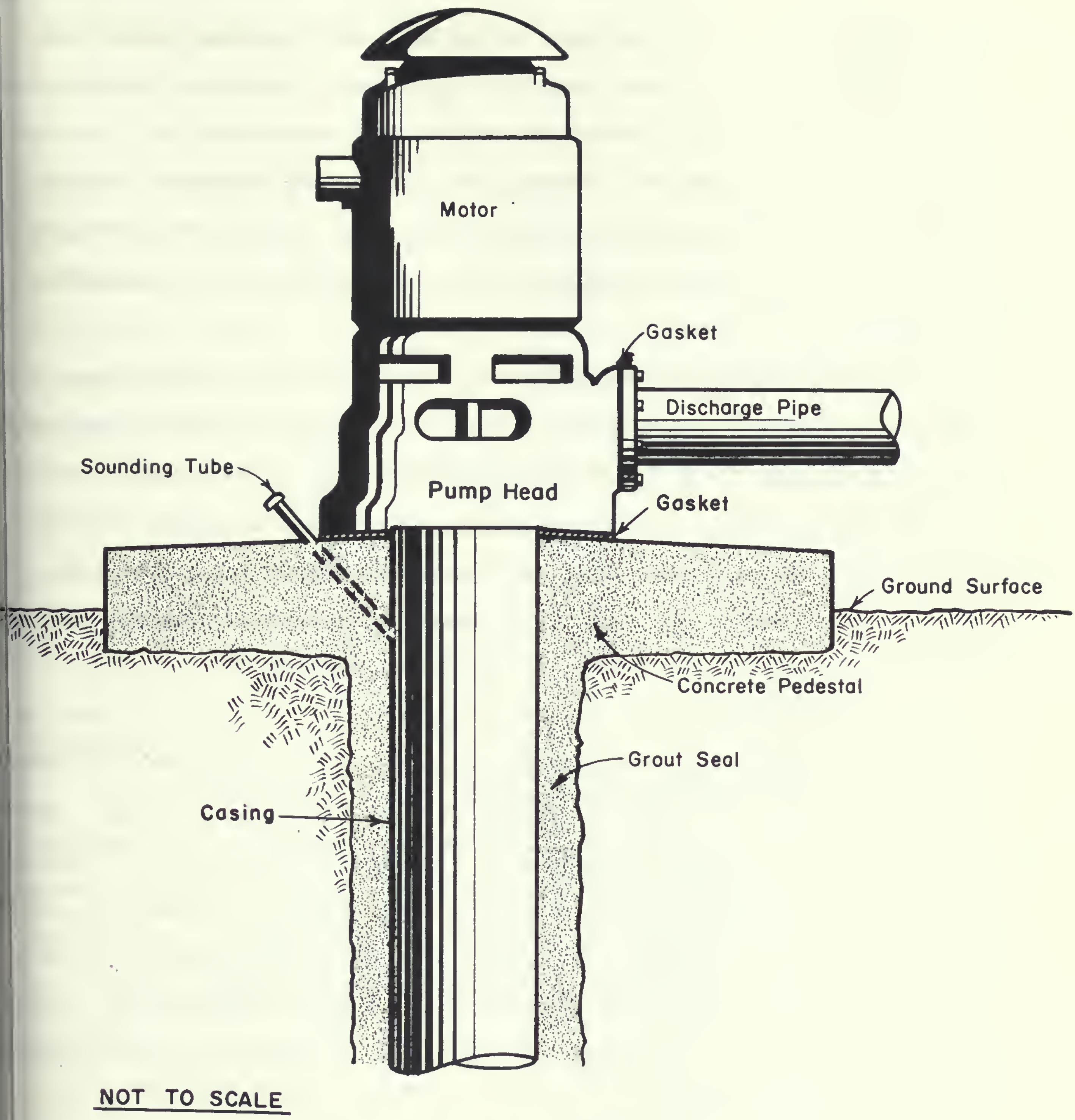

Figure 5

SURFACE FEATURES OF A PROPER
WATER WELL INSTALLATION

Water may be discharged from the pump either above ground surface throug a discharge head in the base of the pump, or below ground surface through a discharge elbow. A discharge pipe is jointed to the head or elbow and should be connected so that the joint is watertight. Field inspections of wells, in conjunctio with investigations conducted throughout California by the Department of Water Resources, indicate that discharge piping on most wells is above ground surface, an that the joint between the discharge head and the discharge pipe is generally watertight.

The most obvious opening at the top of a well is the annular space, i.e. the space between the casing and the sides of the hole. A discussion of protectic for the space below the ground surface is provided on page 119. Although protection against the influx of harmful substances into the annular space is simple an inexpensive, well installations without such safeguards are still found. The required protection can be provided with the solution of another problem, that of providing a foundation structure upon which to set the pump.

The foundation structure, called the pump base or slab, also serves to hold the upper part of the casing in place. Usually the pump pedestal is a concr slab or block which surrounds and extends out a few feet from the casing. Vertic it may extend from several inches to a few feet above and below ground. Even tho the pump may be offset from the well or is a submersible pump, construction of a pedestal or slab is desirable. In addition to adequate size, pedestals should be constructed so as to slope away from the pump and casing. Unfortunately, in thos areas of California where subsidence is severe, the construction of pump pedestal has little practical value.

Well Pits. A well pit is an installation in which the pump is placed below ground surface. The usual reason for placing the pump below ground is to le it in line with discharge lines situated underground and, in areas where freezing i a problem, to keep the whole system below the frost line. Frequently, surface ar other waters flow or seep into and accumulate in pits. Observations made during field investigations indicate that many well pits are not watertight and have no means for automatic removal of drainage. Well pits often contain stagnant water around the pumps. Because they are such a hazard, their use should be avoided.

The need for pits has been virtually eliminated by the development over the last 20 years of a commercial device, popularly known as a "pitless adapter". This device is an undergound discharge assembly which provides for undergound connections to the well and pump and for the extension of the casing above ground. In addition, work can be done on the well or the pump without disturbing the underground discharge line. Until recently, pitless adapter units were available only for small diameter wells; now they range up to 24 inches in diameter.

Pump Houses. As considered here, a pump house is an enclosed structure in which the top of the well and the pump are located. If a well is constructed properly, a pump house is not necessary to safeguard the quality of ground water. However, where a pump house is installed, it should be provided with a floor drain to remove waste water from inside the house.

Subsurface Features

The main part of a water well installation is the subsurface portion. The walls must be maintained against collapse and there must be a channel for the movement of the water up and out of the well. Installation of a lining or casing fulfills both requirements and, in addition, provides protection for the quality of water pumped. The use of casing also permits selective use of water from specific aquifers.

With the casing temporarily in place, the space between the casing, and the wall -- the annular space -- may have to be dealt with. If the space is very wide, the casing must be restrained so that it will not be moved or tilted. At the same time, the annular space often functions as a part of the operating well as is the case in the gravel-packed well. Of more importance, however, is the elimination of these sections of the annular space that can function as a channel for the flow of unsanitary or other undesirable water into the well.

Installation of the casing and disposition of the annular space are the major subsurface construction features of a well. Both features merit careful consideration because all the water produced passes through them. Accordingly, the following discussion deals with casing material and its installation, and the disposition of the annular space, including the upper annular space, the sealing off of various strata, and gravel-packed wells. Figure 6 shows the relative positions of various subsurface construction components in a well.

Casing Material. Almost all wells are cased or lined. However, if drilled in consolidated rock material, the entire well, or a portion of it, might not be cased. Only under unusual circumstances should a well be completely uncased.

The casing is under continual stress resulting from forces imposed duri installation of the casing, from static and kinematic forces imposed by soil, wat, and weight of pump and column pipe, and from seismic forces. Therefore, the casi should be selected to withstand such stresses. Other factors that tend to weaken casing -- metal casing in particular -- result from the corrosive and electrolyti action of water and soil.

Although steel is the most common casing material, a variety of materia are used. Other metals used for casing include stainless steels, cast iron, and silicon bronze, monel, and cupro-nickel alloys. Aluminum has been tried experimentally. Steel pipe which has been lined with asphalt or cement-mortar, plastic coated or galvanized, has served as casing. Among the nonmetals used are asbesto cement pipe, plastics, particularly polyvinyl chloride (PVC) pipe, precast concrete pipe, synthetic wood, clay pipe, and epoxy-bound fibre glass, the newest cas material to be used [76]. Concrete, both plain and reinforced, precast concrete rings, brick, and wood (although generally it is to be avoided) and steel have been used to line dug wells.

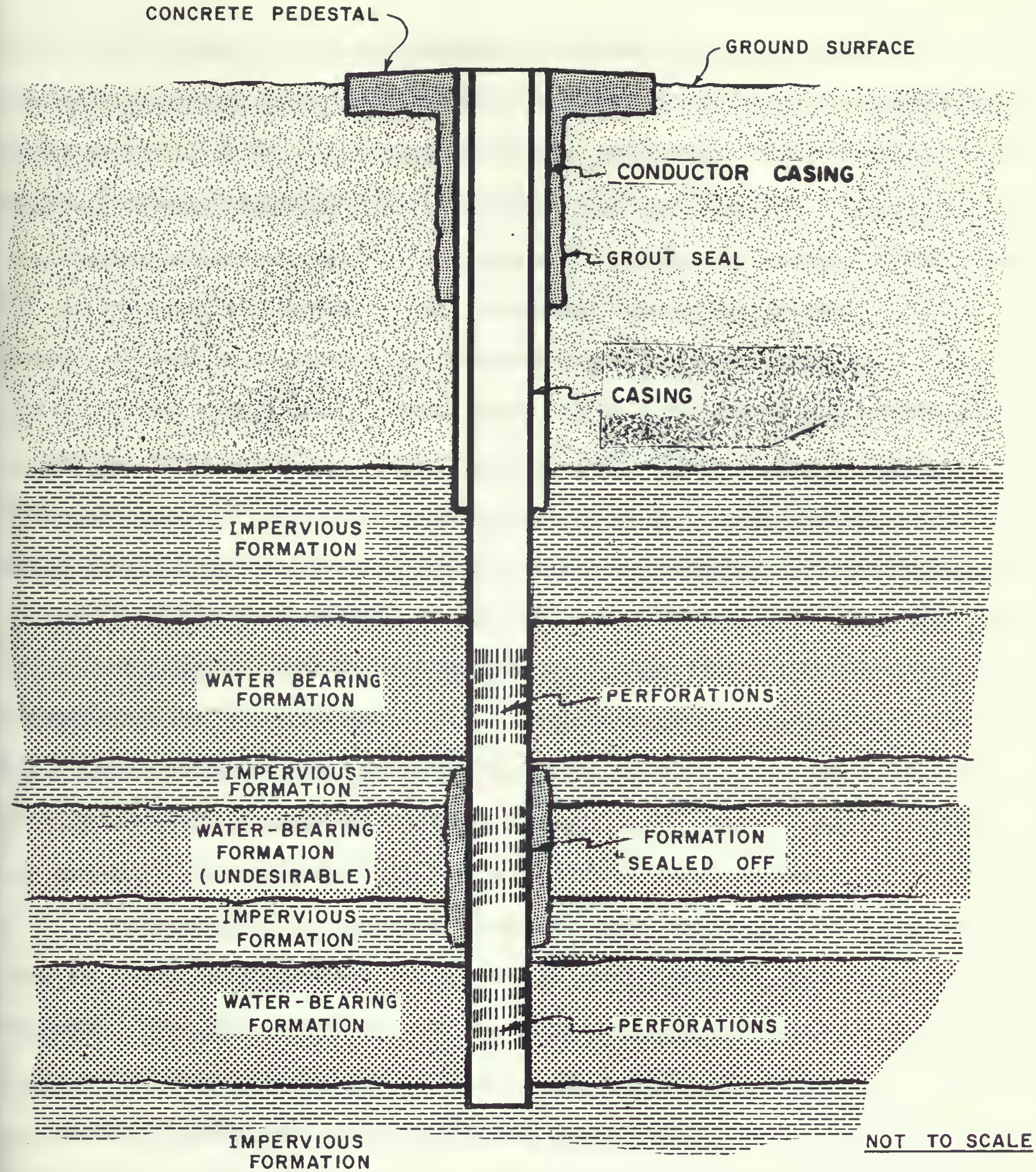

Figure 6

TYPICAL WELL CONSTRUCTION FEATURES

Of the materials listed above, only steel can be driven; all the others, including steel pipe with noncohesive brittle linings, must be set in place. However, these other materials have certain advantages: most are corrosion-resistant or noncorrosive, and some are less expensive then steel (and conversely some are more costly than steel). All of them merit cosideration as casing material.

Casing made of wood is generally unsatisfactory for water wells. Galvanized sheet metal pipe is also an unsatisfactory material because it is too thin and the joints and longitudinal seams are not watertight.

The most commonly used lining materials are tubular-steel products. Steel is particularly suited to cable tool drilling, since it is the only practica material that can withstand driving or the pressure imposed by jacking. An estimated 80 percent of the water well drillers in California use steel casing or pipe. Unfortunately, the terms "casing and pipe" are used interchangeably and designate a variety of tubular products; this is the source of much confusion in the field of water well construction. There is however, a distinguishing differe between pipe and casing. Pipe is manufactured in cylindrical form at the producin mill, whereas casing is made cylindrical by a fabricator from steel sheets or plates produced at a mill. Thus, casing is essentially fabricated pipe. The rea for the difference in manufacture is because the demand for prefabricated pipe fo use in the transmission of water, oil, and gas far exceeds the demand for casing.

Line pipe and standard pipe are made by processes which conform to standards of the American Petroleum Institute (API) or American Society for Testing Materials (ASTM). Unfortunately, standards have not been established for all the steels from which well casing is fabricated, and because of the relativel small quantity produced, standards may not be established for sometime to come. However, this is no reflection on the quality of the products produced nor on the integrity of the producers.

In addition to plates and sheets made in accordance with ASTM standards, the major steel producers market steels designed specifically for use as casing. Well casing is fabricated in single or double thicknesses. The latter is constructed of two concentric single casings 4 feet long, placed together by telescoping one cylindrical section halfway along another and staggering the joints.

Although it is possible to have pipe or casing made to any desired diameter or thickness, manufacturers and fabricators produce products they consider to be in common use. Pipe diameters range from 4 to 36 inches with thicknesses up to one-half inch. Steel plate thicknesses are three-sixteenths to five-sixteenths of an inch with fabricated diameters between 8 and 30 inches. Sheet thicknesses produced run from 12 gage to 6 gage with fabricated diameters of 6 to 24 inches for both single- and double-wall casing.

Perforations and Well Screens. Perforated casings and specially designed and fabricated casing components called "screens" are installed in unconsolidated material to permit the water to flow freely into the well, to prevent sand from moving into the well with the water, and to prevent caving of the unstable material.

Perforations are made by drilling, sawing, punching, or cutting holes into the casing. Nonmetallic casings, such as concrete or asbestos cement, have slotted (rectangular) perforations. In metallic casings, the holes may be rectangular (slots), round or ragged and irregular. Some steel casings, particularly casings that are driven, are perforated in place by means of a perforator (called a "knife"). In commenting on slot openings as related to corrosion, T. P. Ahrens states:

> "... The more uniform the distribution of the slot openings, the better. Large, relatively widely placed slot openings result in head losses from convergence of the stream flow toward the slot openings and high velocities through the slots. Slots should also be smoothly punched, cut, or otherwise formed, as rough-torn edges are an initial point favorable not only to corrosion attack but also for deposition and encrustation. In addition, the slots should not be of uniform cross section, but should increase in width toward the inside of the casing...."(2)

Although perforated casings are satisfactory, they are less efficient than well screens. This is because, if properly designed, the open area of the screen will approach or exceed the open area that exists naturally in the water-bearing aquifer (as measured by the porosity). This minimizes the head loss in the movement of the water through the openings.

Screens are particularly useful where sand is a problem and where the water-bearing formations are thin. These continuous-slot (or "wire-wound") screen in use for about 50 years in central and eastern United States, have not been used in California until just recently. They are made of stainless steel, silicon bronze (everdur metal) red brass, silicon red brass, monel (nickel-copper) and steel. While they cannot be driven, methods have been devised for their installation in wells constructed by the cable tool method. Variations of the continuou slot screen have been made of plastic (particularly PVC); however, they are limite to small diameter wells for reasons of strength.

Louvered or "shutter" screens might best be classed as between perforated casing and continuous-slot screens. The louver openings which may be vertica (parallel to the axis of the screen) or horizontal (circumferential) are produced by stamping, which forces the metal outward. The material can be stainless steel, steel, or iron sometimes galvanized or coated with plastic, asphalt, or aluminum paint, or everdur.

<u>Installation of Casing</u>. Proper installation of casing is a requisite to proper well construction. Damage to casing during placement should be avoided; it must be made structurally stable and joints must be sound and watertight where needed. In addition, although it should be obvious, the casing sections should be in line so that the pumping equipment can function properly and not be under stress due to bending.

More care is required in placement of casing in a well drilled by the cable tool method than in one drilled by the rotary method, since the hole in the cable tool well is usually smaller than the casing, which necessitates driving or jacking the casing, sometimes with considerable force. For this reason, a device that attaches to the lead end of the steel casing called a "drive shoe" is used in most cable tool wells. Drive shoes are made of heavier, tougher material than the casing and are designed to cut through the formations penetrated. The use of drive shoes under these circumstances is universally recommended.

Pipe used in driven wells is subject to bending or breaking, and the joints may be damaged by the force of repeated blows. Concrete casing, used in relatively shallow, large diameter wells, is subject to cracking and failure due to foundation settlement.

Most drillers extend casing to an impervious stratum if feasible. The reasons for seating casing in an impervious stratum are to support it against caving of the materials above and to help stablize it. In the absence of an impervious foundation or when caving formations are encountered, many drillers seat casing in cement.

Reduction in diameter of casing (telescoping) is a common practice within the well drilling industry. Casing diameters are reduced for several reasons: (1) to economize, (2) to permit grouting casing in place, (3) to enable the sealing-off of undesirable water, and (4) because of inability to drive or sink the larger casing farther. The diameter may be reduced several times at successive depth intervals. The United States Public Health Service recommends that, in telescoping casing of different diameters, the annular space between such casings be sealed with a packer or grout to prevent admission of undesirable water.

To prevent the entrance of undesirable water into the well, the casing must be watertight. Of course, watertightness the full length of the casing is not the object since portions of well casings are intentionally opened (i.e., perforated sections or screens). What is important, however, is watertightness along the uppermost sections of the casing, at joints, and at those depths where it is necessary to exclude waters yielded by certain strata.

With regard to the minimum depth below ground at which water may be drawn into wells, and above which the casing should be completely watertight, a common suggestion is that in unconsolidated formations, watertight casing extend at least 5 feet below the lowest anticipated pumping level, and that in unconsolidated rock formations, the watertight casing extend 15 feet into the producing formation.

Most authorities agree that (1) joints should be made watertight; (2) metallic casing joints should be welded or screwed together (using threaded couplings); and (3) concrete, asbestos cement, and clay pipe joints should be surrounded by not less than 6 inches of grout.

The Annular Space. In any method of well construction which involves setting the casing rather than driving it into place, there is invariably a space between the casing and the wall of the hole i.e., the annular space. Even where casing is driven as in cable tool drilling, there is some doubt as to the complete absence of space since in most instances a drive shoe which is larger in diameter than the casing is used. Further, there are few perfect fits between wall and casing the full depth of the well. Formations penetrated vary greatly and there are bound to be openings, pockets, or cavities in the walls of the hole.

From the standpoint of protection of the quality of ground water the annular space is the greatest problem area in well construction. This is because it is a potential channel for the flow of undesirable water. However, the annular space serves a useful purpose, for it can function equally as well as a channel for the movement of desirable water entering the well, e.g., the gravel-packed well. Consequently, only that portion of the annular space which permits entrance of undesirable water into the well need be sealed. The problems are not the same throughout the well. Therefore, discussion of the disposition of the annular space is divided into three topics: the upper annular space; sealing-off strata; and gravel-packed wells.

Upper Annular Space. Undesirable water moving laterally below the ground surface or water which has found a way around the pump base, enters wells by flowing down the annular space. This unwanted water can be kept out by sealing the upper section of the annular space for a sufficient distance below the top of the well with an impervious material.

Sometimes, to ensure that there is a seal, it may be necessary to drill an oversize hole, install an outer casing, and seal the space between the two casings. Another method is to flush out a sufficiently large space around the outside of the casing with a jet of water and fill the space with sealing material. In addition to excluding water, the annular seal is used to maintain the casing in a stable position and to provide protection against corrosive subsoils.

Determination of an adequate depth of seal is dependent on the character of the surface and near-surface formations, depth to water-bearing zone, and the use of the well. All governmental agencies and industry-oriented organizations agree that where contamination or pollution is a possibility, the upper portion of the annular space should be filled with sealing material. However, they do not agree as to the minimum depth below ground to which this seal should extend nor to its thickness.

Most authorities feel that acceptable minimum depth is 20 feet, that a minimum thickness of 1-1/2 inches is sufficient, and that caving formations and soft clays tend to seal themselves. However, there are many reservations about the application of these values in every situation. The preferred sealing material is cement grout (maximum water content of six gallons per sack and 3 to 5 percent bentonite additive) or clay. All authorities consider it important that the sealing material be placed in one continuous operation from the bottom up to preclude separation of the material, formation of air pockets, or segregation of aggregates.

Sealing-Off Strata. Frequently in well construction several aquifers or zones are penetrated. The usual purpose is to be able to draw on as much water as possible or to reach a particularly desirable producing zone. However, the water from one of the zones may be of unsatisfactory quality, and of such quantity that developing and mixing it with the other waters would be detrimental to the total supply. Therefore, such water must not be allowed to move through the annular space and invade zones producing good quality water. Furthermore, the water must not only be prevented from entering the well, but the strata producing the water must be sealed off. When artesian aquifers are penetrated, the annular space opposite the confining impermeable formations may need to be sealed in order to both protect the quality of water in the other zones and maintain the artesian pressure.

Methods and materials used for sealing-off strata during construction are described in numerous publications [40] [44] [51] [57] [67]. The usual method for sealing-off upper strata is to place impervious material in the annular space between the casing and the walls of the drilled hole from the bottom of the zone to be sealed to ground surface. Sometimes the aquifer containing poor quality water lies between aquifers producing water of good quality. To seal off this intermediate aquifer, enough sealing material must be placed in the annular space opposite the aquifer and adjacent materials to prevent movement of the poor quality water into the well or into the other aquifers. Sealing off poor quality waters that lie below good quality waters, or "bottom" waters as they are called, entails plugging the bottom of the well both inside the casing and in the annular space.

Gravel-packed Wells. Although the annular space (assuming there is one) around the casing of a nongravel-packed well usually serves no purpose, it does function in the operation of a gravel-packed well and is purposely enlarged for this reason. The principal reasons for constructing gravel-packed wells are to increase the effective diameter of the well, to prevent fine-grained material from entering the well, and to increase the yield of the well by allowing numerous thin aquifers to produce water.

In furthering the objectives of gravel-packing, many wells in the State are, and have been, gravel-packed from top to bottom. Thus, the gravel envelope becomes a storage tank for all the water free to gravitate to, or to be drawn into, the well. However, from the standpoint of protection of ground water quality in and around the well, gravel-packing "all the way" is unsafe. This is because a gravel envelope can be an excellent conveyance channel for the movement of contaminants or pollutants and for intermingling of waters of various native qualities.

Consequently, certain protective measures must be taken if wells are to be gravel-packed. Where a conductor casing (outer casing) is used, the annular space between the conductor and the walls of the drilled hole are sealed. If a conductor casing is used, the gravel pack does not extend to the top unless the top is covered with a watertight cap. Where it is intended that outer casing be pulled after gravel packing, the space between the inner casing and the hole is left free of gravel and instead is filled with sealing material for the desired depth. Sometimes both the space between the two casings and between the outer casing and hole are sealed.

During construction of a gravel-packed well an access opening (sometimes more than one) is provided for addition of gravel to the gravel envelope. As with other openings to the well, such access holes can be protected against the entrance of undesirable water or foreign materials by caps or other suitable means.

Well Development

Well development is essentially the process of removing fine-grained materials from the water-bearing formation adjacent to the perforated (or screened) interval of the casing. It is exceedingly important for proper development is required to obtain the optimum yield with minimum drawdown, to reduce sanding, and to lengthen the economic life of the well.

Development consists of some method of loosening the fine material in water-bearing zones, drawing the fines into the well shaft, and then removing them from the well. A variety of methods are used, including (1) overpumping (2) surging by alternately starting and stopping the pump, (3) surging by use of a plunger or compressed air, and (4) jetting with water or air. In addition, chemicals and explosives are sometimes used.

Overdevelopment of a well can result in the formation of a cavity in an aquifer due to the removal of too large a volume of fine-grained material. In areas where ground water is confined, an overlying incompetent confining clay layer may collapse as a result of this cavity and allow vertical movement of water from one aquifer to another. Under certain conditions this vertical movement must be prevented. Also, careless or hurried development practices may cause collapse of well casing and permit interchange of water between aquifers.

Many California drillers use a variety of methods for developing wells, the choice of method depending upon conditions prevailing at any particular well. The most common method is by pumping water from the well at a rate exceeding the expected normal rate of pumping (overpumping). Introduction of dry ice, surging the well, and the use of explosives are also development methods employed in

California. Details regarding methods used in developing wells can be found in references (44) (57).

Well Disinfection

Equipment and materials used in the construction of wells (including development) are easily subject to contamination. Consequently, protective measures are necessary before the well is placed in production, particularly if the water is to be used for human consumption.

Pumping will normally remove contamination introduced during the construction or repair of a well; however, safe water can be more quickly and assuredly produced by disinfection of the well. In general, procedures used in well disinfection involve the following: (1) pumping the well until clear of turbidity, (2) adding chlorine solution to the well, (3) mixing the solution with the water in the well, (4) letting the well stand with disinfecting solution in it, and (5) pumping the well until free of the solution. The process is repeated when necessary. A procedure for disinfecting a well is presented in Appendix E.

Chlorine solutions used for disinfecting are made by dissolving calcium hypochlorite, sodium hypochlorite, or gaseous chlorine in water; however, the latter is practical only where large quantities of disinfectant are required. Calcium hypochlorite is a white, granular product sold under the trade names of HTH, Perchloron or Pittchlor. Household bleaches such as Clorox and Purex are made of sodium hypochlorite dissolved in water and are commonly used by drillers for disinfecting wells.

APPENDIX D

LEGAL POWERS AND LIMITATIONS
OF THE STATE AND LOCAL AGENCIES
WITH RESPECT TO GROUND WATER AND WATER WELLS

APPENDIX D

LEGAL POWERS AND LIMITATIONS OF THE STATE AND LOCAL AGENCIES WITH RESPECT TO GROUND WATER AND WATER WELLS

In formulating recommendations for standards of water well construction and sealing of abandoned wells, consideration should be given to the scope and adequacy of existing laws and regulations governing such construction and sealing.

Although there have been for several years state laws regarding the licensing of water well drillers, the capping of artesian wells, and the protection of water quality, there has been, until 1967, no statewide authority for prescribing and enforcing standards for construction or sealing of water wells. However, local agencies do have the authority to prescribe and enforce such standards on a local basis. A number of cities and counties have ordinances regulating water wells. These range in scope from simply requiring a permit to construct a well to prescribing detailed standards relating to location, construction, and sealing of water wells. In 1967 legislation was enacted authorizing the State to require cities and counties to adopt satisfactory ordinances governing well standards in critical areas or itself to adopt such ordinances upon failure of the cities and counties to do so.

State legislation relating to water well drillers, water wells, and protection of ground water, and state and local regulations pertaining to water well construction and abandonment, are considered in this appendix.

State Regulation

Legal Basis

Fundamentally, the legal basis for regulation by the State of the use of ground water is the police power, which is inherent in our form of government. It is not the purpose of this appendix to discuss the nature and extent of such power. Attention is directed, however, to the provisions of the constitutional amendment of 1928 which added Section 3 to Article 14 of the California Constitution. This section provides:

> "SEC. 3. It is hereby declared that because of the conditions prevailing in the State the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare. The right to water or to the use or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water. Riparian rights in a stream or water course attach to, but to no more than so much of the flow thereof as may be required or used consistently with this section, for the purposes for which such lands are, or may be made adaptable, in view of such reasonable and beneficial uses; provided, however, that nothing herein contained shall be construed as depriving any riparian owner of the reasonable use of water of the stream to which his land is riparian under reasonable methods of diversion and use, or of depriving any appropriator of water to which he is lawfully entitled. This section shall be self-executing, and the Legislature may also enact laws in the furtherance of the policy in this section contained."

The substance of the 1928 constitutional amendment has been codified in Sections 100 and 101 of the Water Code. In addition, Section 104 of the Water Code provides:

> "104. It is hereby declared that the people of the State have a paramount interest in the use of all the water of the State and that the State shall determine what water of the State, surface and underground, can be converted to public use or controlled for public protection."

Section 105 of the Water Code provides:

> "105. It is hereby declared that the protection of the public interest in the development of the water resources of the State is of vital concern to the people of the State and that the State shall determine in what way the water of the State, both surface and underground, should be developed for the greatest public benefit."

Mention should also be made of Section 106, which provides:

> "106. It is hereby declared to be the established policy of this State that the use of the water for domestic purposes is the highest use of water and that the next highest use is for irrigation."

In Tulare Irrigation District v. Lindsay-Strathmore Irrigation District, 3 Cal. 2d 489, 45 P. 2d 972, the Supreme Court of California held that the 1928 constitutional amendment comprises "a reasonable exercise of the police power, and, as such, constitutes a lawful abridgement of the riparian right." The court further stated:

> "That the protection and conservation of the natural resources of the State is in the general welfare and serves a public purpose, and so constitutes a reasonable exercise of the police power, is now so well settled that no further citation of authority is necessary."

In the Tulare case as well as others construing the constitutional amendment, it is held that the doctrine of "reasonable use" applies not only to riparian rights, but as well to all other rights to the use of water of whatever character, including ground water. See Peabody v. Vallejo, 2Cal. 2d 351, 40 P. 2d 486; Lodi v. East Bay Municipal Utility District, 7 Cal. 2d 316, 60 P. 2d 439; Rancho Santa Margarita V. Vail, 11 Cal. 2d 501, 81 P. 2d 533; Gin S. Chow v. Santa Barbara, 217 Cal. 673, 22P. 2d 5.

It therefore follows that the police power extends to a reasonable regulation of the use of ground water and of activities affecting beneficial use of ground water necessary to protect the public interest in that vitally important natural resource.

Existing Laws

There now are State laws governing standards of construction, repair, alteration, sealing, or abandonment of water wells, as well as laws which are concerned with water well drillers and protection of the quality of ground waters. These laws are presented herein.

Water Well Investigations and Reports by the Department of Water Resources. Water Code Section 231 authorizes the Department of Water Resources to investigate conditions of damage to the quality of underground waters, which conditions are or may be caused by improperly constructed, abandoned or defective wells and to report to the appropriate regional water quality control board its recommendations for minimum standards of well construction in any particular locality in which it deems regulation necessary, and to report to the Legislature its recommendations for proper sealing of abandoned wells. The full text of Section 231 follows:

> "231. The department, either independently or in cooperation with any person or any county, state, federal or other agency, shall investigate and survey conditions of damage to quality of underground waters, which conditions are or may be caused by improperly constructed, abandoned or defective wells through the interconnection of strata or the introduction of surface waters into underground waters. The department shall report to the appropriate regional water quality control board its recommendations for minimum standards of well construction in any particular locality in which it deems regulation necessary to protection of quality of underground water, and shall report to the Legislature from time to time, its recommendations for proper sealing of abandoned wells.

Water Well Reports and Water Well Standards. Prior to 1967, state law concerning the filing of water well drillers' reports, first enacted in 1949, was contained in Chapter 7 of Division 4 of the Water Code, Sections 7076 through 7078. Chapter 1088, Statutes of 1965, expanded these provisions, and Chapter 323, Statutes of 1967, amended and recodified these provisions in Chapter 7 (commencing with Section 13700) of Division 7 of the Water Code.

Provisions governing the adoption of water well standards were added in the new chapter.

Chapter 7 of Division 7 of the Water Code contains, in Section 13700, a declaration of policy that the people of the State have a primary interest in the location, construction, maintenance, abandonment and destruction of water wells, which activities directly affect the quality and purity of underground waters. Section 13710 defines "well" or "water well" as used in the chapter to mean any artificial excavation constructed by any method for the purpose of extracting water from, or injecting water into, the underground. It excludes oil and gas wells, or geothermal wells constructed under the jurisdiction of the Department of Conservation, except those wells converted to use as water wells. It also excludes wells used for the purpose of dewatering excavation during construction or for the purpose of stablizing hillsides or earth embankments.

Commencing at Section 13750, Chapter 7 requires every person who intends to dig, bore, or drill a water well, or who intends to deepen or reperforate any such well, or to abandon or destroy a water well, to file with the Department of Water Resources a notice of intent prior to commencing such work. Such advance notice need not be given if the work must be accomplished immediately in order to prevent damage to persons or property due to the loss of an existing water supply, but the notice must be filed as soon as possible thereafter, but in any event not more than five days after commencement of such work.

The notice of intent shall be made on forms furnished by the Department and shall contain such information as the Department may require, including, but not limited to:

(a) Description of the well site sufficiently exact to permit location and identification of the well;

(b) Proposed date of construction;

(c) The use for which the water well is intended;

(d) The work to be done and a description of type of construction;

(e) In event of late filing, the reasons therefor.

Within the 30 days after completion of the work, a report of completion must be filed with the Department. The report shall be made on forms furnished by the Department and shall contain such information as the Department may require, including, but not limited to:

(a) Description of the well site sufficiently exact to permit location and identification of the well;

(b) Detailed log of the well;

(c) Description of type of construction;

(d) Details of perforation;

(e) Methods used for sealing off surface or contaminated waters.

Failure to comply with the reporting requirements, or willful and deliberate falsification of any report, is a misdemeanor.

It is provided that completion reports, which include detailed well logs, shall not be made available for inspection by the public but shall be made available to governmental agencies for use in making studies. It is also provided that any such report shall be made available to any person who obtains a written authorization from the owner of the water well.

Provisions for requiring water well standards are contained in Sections 13800 through 13806. These provisions require the Department of Water Resources to report to the appropriate regional water quality control board and to the State Department of Public Health the results of any study showing that water well construction standards are needed to protect water quality in a given area. The report shall contain such recommended standards for water well construction, maintenance, abandonment, and destruction as, in the Department's opinion, are necessary to protect the quality of any affected water. The regional board must then hold a public hearing to determine if such need exists and to determine the objectives to be attained by such standards. If the regional board finds that standards are needed, it shall determine the area affected and notify each affected city or county of the need and of the objectives deemed proper and necessary. It shall also forward the Department's recommended standards.

Each such affected county or city shall within 120 days of receipt of the report of the regional board adopt an ordinance establishing standards of water well construction, maintenance, abandonment, and destruction for the area designated by the regional board. Such standards shall take effect 60 days from the date of their adoption unless the regional board, on its own motion or on the request of any affected person, holds a public hearing and determines that the standards are not sufficiently restrictive. If it makes such a finding, the regional board shall recommend the standards it determines are necessary. If the county or city fails to adopt standards determined necessary by the regional board, the regional board may adopt standards for the area. Any action or inaction of a regional board may be reviewed by the State Water Resources Control Board on its own motion, and any such action must be reviewed on the motion of any affected person, county or city.

The full text of Chapter 7 of Division 7 of the Water Code follows:

CHAPTER 7. WATER WELLS

Article 1. Declaration of Policy

"13700. The Legislature finds that the greater portion of the water used in this state is obtained from underground sources and that such waters are subject to impairment in quality and purity, causing detriment to the health, safety and welfare of the people of the state. The Legislature therefore declares that the people of the state have a primary interest in the location, construction, maintenance, abandonment and destruction of water wells, which activities directly affect the quality and purity of underground waters.

Article 1.5. Definitions

"13710. "Well" or "water well" as used in this chapter, means any artificial excavation constructed by any method for the purpose of extracting water from, or injecting water into, the underground. This definition shall not include: (a) oil and gas wells, or geothermal wells constructed under the jurisdiction of the Department of Conservation except those wells converted to use as water wells; or (b) wells used for the purpose of (1) dewatering excavation during construction, or (2) stabilizing hillsides or earth embankments.

Article 2. Reports

"13750. Every person who hereafter intends to dig, bore, or drill a water well, or who intends to deepen or reperforate any such well, or to abandon or destroy a water well, shall file with the department a notice of intent to engage in such construction, alteration, destruction, or abandonment prior to commencing such construction, alteration, destruction, or abandonment; provided, that when such construction, alteration, destruction, or abandonment must be accomplished immediately in order to prevent damage to persons or property due to the loss of an existing water supply, such notice shall be filed with the department as soon as possible thereafter, but in any event not more than five days after commencement of such construction, alteration, destruction, or abandonment or repair.

The report shall be made on forms furnished by the department and shall contain such information as the department may require, including, but not limited to: (a) description of the well site sufficiently exact to permit location and identification of the well; (b) proposed date of construction of well; (c) the use for which the water well is intended; (d) the work to be done and a description of type of construction; and (e) in event of late filing, the reasons therefor.

"13751. Every person who hereafter digs, bores or drills a water well or abandons or destroys a water well, or who deepens or reperforates any such well, shall file with the department a report of completion of such well within 30 days after its construction or alteration has been completed.

The report shall be made on forms furnished by the department and shall contain such information as the department may require, including, but not limited to: (a) description of the well site sufficiently exact to permit location and identification of the well;

(b) detailed log of the well; (c) description of type of construction; (d) details of perforation; and (e) methods used for sealing off surface or contaminated waters.

"13752. Reports made pursuant to Section 13751 shall not be made available for inspection by the public but shall be made available to governmental agencies for use in making studies; provided, that any report shall be made available to any person who obtains a written authorization from the owner of the water well.

"13753. Every person who hereafter converts, for use as a water well, any oil or gas well originally constructed under the jurisdiction of the Department of Conservation pursuant to the provisions of Article 4 (commencing with Section 3200), Chapter 1, Division 3 of the Public Resources Code, shall comply with all provisions of this chapter.

"13754. Failure to comply with any provision of this article, or willful and deliberate falsification of any report required by this article, is a misdemeanor.

Before commencing prosecution against any person, other than for willful and deliberate falsification of any report required by this article, the person shall be given reasonable opportunity to comply with the provisions of this article.

"13755. Nothing in this chapter shall affect the powers and duties of the State Department of Public Health with respect to water and water systems pursuant to Chapter 7 (commencing with Section 4010) of Division 5 of the Health and Safety Code. Every person shall comply with this chapter and any regulation adopted pursuant thereto, in addition to standards adopted by any city or county.

Article 3. Quality Control

"13800. The department, after such studies and investigations pursuant to Section 231 as it finds necessary, on determining that water well construction, maintenance, abandonment, and destruction standards are needed in an area to protect the quality of water used or which may be used for any beneficial use, shall so report to the appropriate regional water quality control board and to the State Department of Public Health. The report shall contain such recommended standards for water well construction, maintenance, abandonment, and destruction as, in the department's opinion, are necessary to protect the quality of any affected water.

"13801. The regional board shall hold a public hearing on the need to establish such standards for the area involved and to determine the objectives to be attained by such standards.

"13802. If the regional board finds that standards of water well construction, maintenance, abandonment, and destruction are needed in any area to protect the quality of water used, or which may be used, for any beneficial use, it shall determine the area to be involved and so report to each affected county and city in the area, including in such report the objectives determined by the board as proper and necessary objectives for such standards. The report shall also contain any standards which have been recommended by the department.

"13803. Each such affected county and city shall, within 120 days of receipt of the report, adopt an ordinance establishing standards of water well construction, maintenance, abandonment, and destruction for the area designated by the regional board. Prior to adoption of such ordinance each affected county and city shall consult with all interested parties, including licensed well drillers. A copy of such ordinance shall be sent to the regional board on its adoption and the regional board shall transmit such ordinace to the department for its review and comments.

"13804. Such county and city standards shall take effect 60 days from the date of their adoption by the county or city unless the regional board, on its own motion, or on the request of any affected person, holds a public hearing on the matter and determines that the county or city standards are not sufficiently restrictive to protect the quality of the affected waters. If the board makes such a determination it shall so report to the affected county or city and also recommend the standards, or modification of the county or city standards, which it determines are necessary.

"13805. If a county or city fails to adopt an ordinance establishing water well construction, maintenance, abandonment, and destruction standards within 120 days of receipt of the regional board's report of its determination that such standards are necessary pursuant to Section 13802, or fails within 90 days to adopt or modify such standards in the manner determined as necessary by the regional board pursuant to Section 13804, the regional board may adopt standards for water well construction, maintenance, abandonment, and destruction for the area. Such regional board standards shall be enforced in the same manner and shall have the same force and effect as if adopted as a county or city ordinance.

"13806. Any action, report, determination, or standard taken or adopted by a regional board pursuant to this article may be reviewed by the state board on its own motion, and shall be reviewed by the state board on the request of any affected person, county, or city, in the same manner as other action or inaction of the regional board is reviewed pursuant to Section 13025. The state board has the same powers as to the review of action or inaction of a regional board under this article as it has as to other action or inaction of a regional board under Section 13025, including being vested with all the powers granted a regional board to initially determine the need in an area for water well construction, maintenance, abandonment, or destruction standards if it finds that appropriate action has not been taken by a regional board."

Contractors License Law. Except as noted below, Sections 7026.3 and 7049 of the Business and Professions Code require any person engaged in the business of drilling, digging, boring, or otherwise constructing, deepening, repairing, reperforating, or abandoning water wells to be a licensed contractor under the Contractors License Law, as provided in Division 3, Chapter 9 (commencing at Section 7000), of the Business and Professions Code.

The law prohibits any person from engaging in the business or acting in the capacity of a contractor without having a license issued by the Contractors' State License Board. However, there are certain exemptions. Included among the exemptions are a person, or his employees, who constructs, or deepens, repairs, or reperforates a water well for his own use; representatives of state and federal governments; representatives of local governments and political subdivisions of the State; public utilities operating under the regulation of the Public Utilities Commission; the drilling and operation of oil and gas wells when performed by an owner or lessee; construction on federally-owned sites; and jobs costing less than one hundred dollars ($100.00). (Business and Professions Code, Sections 7026.3 and 7040-7048). Prior to amendments of the law in 1959, drillers of wells to be used solely for agricultural purposes were also exempted, but that exemption no longer applies.

Sewer Wells. There are a number of prohibitions contained in Division 5, Part 2, Chapter 4, Article 2, of the Health and Safety Code imposed for the purpose of preventing pollution or contamination of water. Most of these provisions are designed to protect the purity of drinking water in rivers, creeks, ponds, streams, lakes, and reservoirs. Section 4458, which relates directly to underground water, provides:

> "4458. No person shall construct, maintain or use any sewer well extending to or into a subterranean water-bearing stratum that is used or intended to be used as, or is suitable for, a source of water supply for domestic purposes, except that where a regional water quality control board finds that water quality considerations do not preclude controlled recharge of such stratum by direct injection, water reclaimed from sewage may be injected by a well into such stratum after a public hearing and a finding by the State Board of Public Health that the proposed recharge will not impair the quality of water in the receiving aquifer as a source of water supply for domestic purposes. Said board may make and enforce such regulations pertaining thereto as it deems proper. Nothing in this section shall be construed to affect the authority of the State Water Resources Control Board or regional water quality control boards to prescribe and enforce requirements for such discharge.
>
> 'Sewer well' as used in this section includes all of the following:
>
> (a) Any hole dug or drilled into the ground, and intended for use as a water supply, which has been abandoned and is being used for the disposal of sewage.
>
> (b) Any hole dug or drilled into the ground, used or intended to be used for the disposal of sewage."

<u>Waste From Artesian Wells</u>. Waste of water from artesian wells is prohibited by Article 4 of Chapter 2.5 of Division 1 of the Water Code, comprising Sections 300-311, inclusive, which are quoted in full as follows:

> "300. For the purposes of this article, an artesian well is any artificial hole made in the ground through which water naturally flows from subterranean sources to the surface of the ground for any length of time.
>
> "301. For the purposes of this article, waste is the causing, suffering, or permitting any water flowing from an artesian well, to run either:
>
> (a) Into any natural watercourse or channel, or into any bay or pond, unless the water is used thereafter for irrigation or domestic use.
>
> (b) Into any street, road, or highway.
>
> (c) Upon the land of any person or upon the public land of the United States or of the State, unless it is used thereon for irrigation, domestic use, or the propagation of fish.
>
> "302. The use of any water flowing from an artesian well for the irrigation of land, whenever over 5 percent of the water received on the land for irrigation purposes is permitted to escape from the land, is waste within the meaning of this article.

"303. Nothing in this article prevents the running of artesian water into an artificial pond or storage-reservoir, if the water is used thereafter for a beneficial use.

"304. A beneficial use under the next preceding section shall not exceed one tenth of one miner's inch of water per acre, perpetual flow, but the person using the water may accumulate that amount within any period of each year.

"305. Any artesian well which is not capped or equipped with a mechanical appliance which will readily and effectively arrest and prevent the flow of any water from the well is a public nuisance.

"306. The owner, tenant, or occupant of the land upon which a well which is a public nuisance under the next preceding section is situated, who causes, permits, or suffers such public nuisance to exist or continue is guilty of a misdemeanor.

"307. Any person owning, possessing, or occupying any land upon which is situated an artesian well, who causes, suffers, or permits water unnecessarily to flow from the well or to go to waste is guilty of a misdemeanor.

"308. Each day's continuance of waste constitutes a new offense.

"309. Any person who violates any of the provisions of this article is punishable for each offense by a fine of not less than twenty-five dollars ($25) and not more than five hundred dollars ($500) or by imprisonment in the county jail for not more than six months, or by both.

"310. All prosecutions for the violation of any of the provisions of this article shall be instituted in the justice court or municipal court of the county in which the well is situated.

"311. Any fine imposed under the provisions of this article may be collected as in other criminal cases, and the justice may also issue an execution upon the judgment therein rendered, which may be enforced and collected as in civil cases."

Abandoned Excavations. Section 24400 of the Health and Safety Code makes it a misdemeanor for a landowner or one in possession of any land to fail to fence, fill, or keep covered any abandoned water well on the land. The exact provisions of the section are as follows:

"24400. Every person owning land in fee simple or in possession thereof under lease or contract of sale who knowingly permits the existence on the premises of any abandoned mining shaft, pit, well, septic tank, cesspool, or other abandoned excavation dangerous to persons legally on the premises, or to minors under the age of twelve years, who fails to cover, fill, or fence securely any such dangerous abandoned excavation and keep it so protected, is guilty of a misdemeanor."

It should be noted that the purpose of the above section is to keep people from falling into a well or other excavation rather than to protect the quality of the underground water, and does not require that abandoned wells be properly sealed so as to prevent contamination of ground water.

Other Powers and Duties of State Agencies

In addition to the functions of state agencies under the above provisions, there are numerous other functions related to the general subject.

Department of Professional and Vocational Standards. The contractors license law, hereinabove discussed, does not provide for any regulation governing well construction. If a well driller possesses sufficient qualifications to secure a water well drilling contractors license, there is nothing in the licensing law, except as hereinafter noted, to prevent him from thereafter drilling any kind of water well he and his employer may choose, no matter what effect such drilling may have on the ground water supply.

There is, however, one measure of control over well drillers who are licensed contractors. Section 7110 of the Business and Professions Code (relating to the contractors' license law) provides that violation by any licensee of any provision of the Health and Safety Code or Water Code, relating to the digging, boring, or drilling of a water well, constitutes a cause for disciplinary action by the Registrar of Contractors. Such action could result in suspension or revocation of the contractor's license. Thus, for example, disciplinary action may be taken against a licensed well driller for failure to file reports required under Chapter 7 of Division 7 of the Water Code or for violating well standards adopted pursuant to said chapter, or for constructing, maintaining, or using any sewer well extending to or into a subterranean water-bearing stratum that is used or intended to be used as, or is suitable for, a source of water supply for domestic purposes in violation of Section 4458 of the Health and Safety Code.

In addition to being subject to disciplinary proceedings, a licensed contractor, as well as any other person, including an unlicensed contractor, may be criminally prosecuted for violations of law which are declared to be misdemeanors. Thus, a licensed or unlicensed well driller could be criminally prosecuted for failure to file a report required by Chapter 7 of Division 7 of the Water Code, or for willful and deliberate falsification of any report required by such chapter, or for constructing a sewer well extending into a subterranean water-bearing stratum suitable for a source of water supply for domestic purposes in violation of Health and Safety Code Section 4458.

State Water Resources Control Board and Regional Water Quality Control Boards. In addition to the power to require adoption of well standards pursuant to Chapter 7 of Division 7 of the Water Code, the regional water quality control boards may recommend minimum standards of construction to well drillers and owners, and may attempt to secure voluntary cooperation pursuant to the authority conferred by Section 13052 of the Water Code, which provides in part as follows:

> "13052. Each regional board, with respect to its region, shall:
>
> (a) Obtain coordinated action in water quality control and in the abatement, prevention and control of water pollution and nuisance by means of formal or informal meetings of the persons involved;
>
> (b) Encourage and assist in self-policing waste disposal programs for industry, and upon application of any person shall advise the applicant of the condition to be maintained in any disposal area or receiving waters into which the waste is being discharged; ...."

In addition to promoting voluntary cooperation, if there is a particular condition of pollution or nuisance, existing or threatened, caused by a defective well, such as through entrance of surface water into ground water or through interconnection of aquifers, a regional board shall prescribe requirements relative to the condition to be maintained with respect to ground water affected thereby (Water Code, Section 13053). Furthermore, any person proposing to discharge sewage or other waste and, upon request of the board, any person presently discharging such waste into the ground water supplies is required to file a report with the regional board which is then required to prescribe requirements as to the nature of such proposed or existing discharge with relation to the conditions existing from time to time in the disposal area or receiving waters (Water Code Section 13054). Any material change or proposed change in the character, location, or volume of any discharge of sewage or other waste likewise is required to be reported (Water Code Section 13054.1). Any person not filing a report upon request of a regional board or the state board is guilty of a misdemeanor (Water Code Section 13054.4). If any person fails to file a report as required by law, an injunction may be issued requiring such person to file the required report and restraining such person from discharging sewage or other waste within the region until the required report has been filed (Water Code Section 13054.5). In prescribing requirements, a board may either fix such requirements in terms of the quality of discharge or in terms of the condition to be maintained in the receiving waters (16 Ops. Cal. Atty. Gen. 203, Opinion No. 50-150, dated December 19, 1950). The board may not, however, specify the design, location, type of construction, or particular manner in which an operation causing or threatening to cause a condition or nuisance is to be corrected (Water Code Section 13064).

The full text of the Water Code sections referred to in this paragraph is as follows:

"13053. Each regional board shall prescribe requirements relative to any particular condition of pollution or nuisance, existing or threatened, in the region.

"13054. Any person proposing to discharge sewage or other waste within any region, other than into a community sewer system, shall file with the regional board of that region a report of such proposed discharge. Upon the request of the regional board, any person presently discharging sewage or other waste within any region, other than into a community sewer system, shall file with the regional board of that region a report of such discharge. The reporting of a discharge of sewage from family dwellings in any area may be waived by the regional board. The regional board, after any necessary hearing, shall prescribe requirements as to the nature of such proposed or existing discharge with relation to the conditions existing from time to time in the disposal area or receiving waters upon or into which the discharge is made or proposed and notify the person making or proposing the discharge of its action. Such requirements may be revised from time to time. After receipt of such notice, the person so notified shall provide adequate facilities to meet any such requirements with respect to the discharge of sewage and other waste.

"13054.1. Any person discharging sewage or other waste within any region, other than into a community sewer system, shall file with the regional board of that region a report of any material change or proposed change in the character, location or volume of the discharge. The regional board, after any necessary hearing, shall prescribe requirements or revised requirements as to the nature of such discharge with relation to the conditions existing from time to time in the disposal area or receiving waters upon or into which the discharge is made or proposed and notify the person making or proposing the discharge of its action. Such requirements may be revised from time to time. After receipt of such notice, the person so notified shall provide adequate facilities to meet any such requirements or revised requirements with respect to the discharge of sewage and other waste.

"13054.2. A regional board, in prescribing requirements, bearing in mind threats to the public health, the aquatic habitat, and other beneficial uses, need not authorize the utilization of the full waste assimilation capacities of the receiving waters

"13054.3. (a) Each regional board, within its region, may specify certain conditions and locations where no direct discharge of sewage or other waste will be permitted.

(b) Each regional board, within its region, may prescribe requirements of the type specified in Section 13054, which shall be applicable to all indirect discharges of sewage from family dwellings within a designated area; provided that before adopting any such requirements, the regional board shall hold a public hearing respecting the adoption of such requirements and on what the boundaries of the area to be affected by such requirements should be. The regional board shall publish notice of such hearing pursuant to Section 6066 of the Government Code and shall give notice by certified mail of such hearing to each landowner in the proposed area at his address as shown on the last equalized assessment roll.

Upon adoption, such requirements shall be enforceable, jointly and severally, against any discharger within the area designated who is in violation thereof.

"13054.4. Any person failing to file a report, upon request of a regional or state board, as required in Section 13054 or 13054.1 is guilty of a misdemeanor. Each day of discharge of sewage or other waste within a region without compliance with the reporting requirements shall constitute a separate offense.

"13054.5. Upon failure of any person or persons to file a report as required by Sections 13054 and 13054.1, a regional board may certify the facts to the district attorney for the county in which the discharge or proposed discharge does or will occur, and the district attorney shall petition the superior court in and for that county for the issuance of an injunction requiring such person or persons to file the required report and restraining such person or persons from discharging sewage or other waste within the region until the required report has been filed. In any such suit, the court shall have jurisdiction to grant, without requiring bond or other undertaking, such prohibitory and mandatory injunction, either preliminary or final, as the facts may warrant.

"13064. No order issued under the provisions of this article shall specify the design, location, type of construction or particular manner in which the operation causing or threatening to cause a condition of pollution or nuisance is to be corrected, and the person so ordered shall be permitted to correct the condition in any lawful manner."

When a regional board finds that a discharge of sewage or other waste is taking place contrary to requirements prescribed by the board, the board shall order the person or persons not complying with the requirements to cease and desist and to comply immediately. If the person or persons fail to comply with the order to cease and desist, the board shall present the case to the district attorney for the county in which the discharge originates. The district attorney shall then request the superior ceurt of said county to issue an injunction restraining the discharging agency from continuing the discharge in violation of the requirements.

The sections of the Water Code which establish the proceedings outlined above for enforcement of the requirements of the water pollution control boards are as follows:

> "13060. When regional board finds that the discharge of sewage or other waste within its region is taking place contrary to any requirements prescribed by the regional board under the provisions of Sections 13053, 13054, 13054.1, 13054.3, and 13055, and that such discharge is threatening to cause or is causing pollution or a nuisance, the board may issue an order to cease and desist and direct that those persons, firms, or corporations not complying with the requirements, comply forthwith.
>
> "13063. Upon failure of any person or persons to comply with any such cease and desist order of the board, the board issuing the order may certify the facts to the district attorney for the county in which the discharge originates or to the Attorney General if the district attorney declines to act. The district attorney or Attorney General, as the case may be, shall petition the superior court in and for that county for the issuance of an injunction restraining such person or persons from continuing the discharge in violation of the requirements. The court shall thereupon issue an order directing the person to appear before the court and show cause why the injunction shouuld not be issued. Thereafter the court shall have jurisdiction of the matter, and proceedings thereon shall be conducted in the same manner as in any other action brought for an injunction pursuant to Chapter 3 (commencing with Section 525), Title 7, Part 2 of the Code of Civil Procedure.
>
> "The court shall receive in evidence the order of the board, evidence as to the validity and reasonableness of the board's requirements as previously established, and such further evidence as the court in its discretion deems proper."

The State Water Resources Control Board is authorized to take action to correct any particular existing or threatened condition of pollution or nuisance whenever a regional board fails to take or obtain appropriate action. This authorization is provided by Section 13025 of the Water Code which is quoted as follows:

"13025. Any action of a regional board pursuant to Section 13053, 13054, 13054.1, or 13054.3, or the failure of a regional board to act may be reviewed by the state board and upon finding that the regional board's action or inaction based upon the evidence before the state board appears to have been inappropriate or improper may direct that appropriate action be taken by the regional board or any other state agency having jurisdiction or may, itself, take such action.

"In taking any such action the state board is vested with the powers granted to the regional boards in Section 13053, 13054, 13054.1, 13054.2, 13054.3, 13054.5, 13055 and Article 3 (commencing at Section 13060) and Article 4 (commencing at Section 13080) of Chapter 4, and the state board shall follow the procedures set forth therein.

"The state board upon finding that a contamination exists and is not being corrected, shall refer the condition to any state agency having jurisdiction."

It should be noted that powers of the regional water quality control boards extend only to the control of "pollution" and "nuisance" resulting from the discharge or disposal of "sewage" or "other waste". These terms are defined in Section 13005 of the Water Code as follows:

" 'Sewage' means any and all waste substance, liquid or solid, associated with human habitation, or which contains or may be contaminated with human or animal excreta or excrement, offal, or any feculent matter.

" 'Other waste' means any and all liquid or solid waste substance, not sewage, from any producing, manufacturing, or processing operation of whatever nature.

" 'Waters of the State' means any waters, surface or underground, including saline waters, within the boundaries of the state as defined and described in Section 1 of Article XXI of of the Constitution and as given greater precision in Sections 170, 171, and 172 of the Government Code.

" 'Pollution' means an impairment of the quality of the waters of the state by sewage or other waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, industrial, agricultural, navigational, recreational or other beneficial use, or which does adversely and unreasonably affect the ocean waters and bays of the state devoted to public recreation.

" 'Nuisance' means damage to any community by odors or unsightliness resulting from unreasonable practices in the disposal of sewage or other wastes."

In Opinion No. 55-236 dated March 30, 1956 (27 Ops. Cal. Atty. Gen. 182), the Attorney General advised the State Water Pollution Control Board that in his opinion liquids containing harmful materials which arise in one stratum intercepted by a water, oil, or gas well and flow through the well into other intercepted strata containing water of good quality come within the definition of industrial waste (which term was changed in 1967 to "other waste"), being a by-product resulting from the producing operation of extracting water, oil, or gas from the ground.

In Opinion No. 55-237 dated April 16, 1956 (27 Ops. Cal. Atty. Gen. 217), the Attorney General also advised the State Water Pollution Control Board that in his opinion the discharge into the waters of the State of sewage or industrial waste containing fine-grained materials results in a pollution where the waste is discharged into water used to recharge ground water basins, and where in the process of percolation of the water the fine-grained materials in the waste settle on and seal the surface through which the recharge occurs, with the result that the recharge is impaired or prevented.

It seems clear, therefore, that where the quality of surface or ground water is impaired, or where impairment is threatened, by sewage or other waste to a degree which adversely and unreasonably affects such waters for beneficial use or which, due to unreasonable practices in disposal, creates damage to any community by odors or unsightliness, the regional water quality control boards are authorized to prescribe requirements to be maintained relative to the quality of such discharge or relative to the quality of the receiving waters, but they are not authorized to prescribe and enforce specific standards for construction, sealing, or abandonment of wells under these provisions.

Regional water quality control boards, therefore, may prescribe requirements as to the quality of ground water which must be maintained by one operating or owning a well. If through faulty construction or inadequate sealing, a well is causing or threatening impairment to quality of ground waters, a regional board may prescribe requirements to be maintained relative to the ground water.

Department of Public Health. In case of a "contamination," which is defined as "an impairment of the quality of the waters of the State by sewage or other waste to a degree which creates an actual hazard to the public health through poisoning or through the spread of disease" (Water Code, Section 13005; Health and Safety Code, Section 5410), the State Department of Public Health may order abatement (Health and Safety Code, Section 5412). (See generally, Health and Safety Code, Division 5, Part 3, Chapter 6, Articles 2 and 3.) Any person who discharges sewage or other waste in any manner which results in contamination is guilty of a misdemeanor (Health and Safety Code, Section 5461).

In addition to the authority conferred upon the Department of Public Health with respect to contamination, the State Board of Public Health is charged with the duty of holding hearings and making findings as to whether proposed injections into the underground of water reclaimed from sewage will impair the quality of the water in the receiving aquifer as a source of water for domestic purposes, and to make and enforce regulations pertaining thereto (Health and Safety Code, Section 4458).

Section 4460 of the Health and Safety Code provides that violations of Article 2 of Chapter 4 of Part 2 of Division 5 of the Health and Safety Code, which imposes numerous prohibitions designed to protect the purity of drinking water, including the prohibitions in Section 4458 relating to sewer wells, may be enjoined by any court of competent jurisdiction at the suit of any person whose supply of water for human or animal consumption or for domestic purposes is or may be affected, or by the Department of Public Health. Section 4461 declares that anything done, maintained, or suffered in violation of any of the provisions of said Article 2 is a public nuisance, dangerous to health, and may be summarily abated as such. Thus violations of said Article 2, including Section 4458, may be enjoined or summarily abated pursuant to Sections 4460 and 4461 of the Health and Safety Code.

In addition, Section 4457 provides:

> "4457. Every person who violates, or refuses or neglects to conform to, any sanitary rule, order, or regulation prescribed by the State Department of Public Health for the prevention of the pollution of springs, streams, rivers, lakes, wells, or other waters used or intended to be used for human or animal consumption, is guilty of a misdemeanor."

The Department of Public Health also exercised control over domestic water distribution systems (Health and Safety Code, Division 5, Part 1, Chapter 7, Sections 4010 through 4038). No person may furnish or supply water to a user for domestic purposes without a permit from the Department of Public Health. The Department may grant a permit only if it determines that the water is pure, wholesome, and potable. As a condition to granting the permit or for not revoking it, the Department may order such changes in the plant, works, system, or water supply as it deems necessary, including changes in the source of the water supply. Violations of the act are a misdemeanor, and injunction and abatement proceedings are available. Thus the Department of Public Health may order work done on wells to make water from the wells safe for human consumption as a condition to approval of permits for distribution of water for domestic purposes.

Department of Water Resources. Mention has already been made of Sections 231 and 13800 of the Water Code, which authorizes the Department of Water Resources to investigate damage to quality of ground waters caused by defective wells and to make recommendations for minimum standards of well construction. Mention has also been made of Sections 13750 through 13755 which requires the filing of certain reports on wells with the department. The department is also authorized under Section 275 of the Water Code to take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water in this State.

Department of Conservation. In considering regulation of water well drilling, attention should be given to the present law in this State governing construction and operation of oil and gas wells and of geothermal wells. Provisions governing operation of oil and gas wells are in Article 4 of Chapter 1 of Division 3 of the Public Resources Code, Sections 3200-3237.

The drilling, operation, maintenance, and abandonment of oil and gas wells has been under the supervision of the Division of Oil and Gas since it was created in 1915. There were laws regarding construction and abandonment of oil and gas wells as far back as 1903; however, no enforcement agency was provided. Consequently, no control was exercised over the construction and abandonment of oil and gas wells prior to 1915. Furthermore, there is no provision under the present law to require adequate sealing of oil and gas wells abandoned prior to 1915.

Present regulation of oil and gas wells is quite extensive. Every owner or operator of any oil or gas well is required to designate an agent who resides in this State, upon whom all orders, notices, and processes may be served. The owner or operator must give notice in writing within five days of the sale, assignment, transfer, conveyance, or exchange by the owner or operator of such well, and of the land, owned or leased, upon which the well is located. The transferee must also give notice.

A notice of intention to drill, redrill, deepen or perform any operation involving the plugging of a well or any operation permanently altering the casing of a well is required to be filed, and a bond to insure completion of the work in accordance with applicable regulations must also be filed. A careful and accurate log, core record, and history of the drilling of each well is required to be kept and filed. No bond may be terminated or cancelled until the well or wells for which it has been issued have been properly completed or abandoned. No well is properly completed until the person performing the work has shown to the satisfaction of the State Oil and Gas Supervisor that the manner of doing the work and the manner of producing oil therefrom are satisfactory. No well is properly abandoned until the person doing the work has shown to the satisfaction of the State Oil and Gas Supervisor that all proper steps have been taken to shut off and exclude all water from oil-bearing or gas-bearing strata encountered in the well, and to protect ground or surface water suitable for irrigation or farm or domestic purposes from the infiltration or addition of any detrimental substance.

Precautions are required to be taken to prevent blowouts, explosions, and fires. Adequate, water-tight metal casings are required, and the owner or operator of a well is required to shut off all water overlying and underlying oil-bearing or gas-bearing strata and prevent any water from penetrating such strata. Steps are required to be taken to shut out detrimental substances from strata containing water suitable for irrigation or domestic purposes and from surface water suitable for such purposes, and to prevent the infiltration of detrimental substances into such strata and into such surface water. Shut-off tests may be ordered when it appears to the Supervisor that water from any well is penetrating oil-bearing or gas-bearing strata or that detrimental substances are infiltrating into ground or surface water suitable for irrigation or domestic purposes. The Supervisor shall order such tests or remedial work as in his judgment are necessary to protect oil and gas deposits from damage by ground water, or to prevent the escape of water into underground formations, or to prevent the infiltration of detrimental substances into ground or surface water suitable for irrigation or domestic purposes, to the best interests of the neighboring property owners and the public. The order shall specify the conditions sought to be remedied and the work necessary to protect such deposits from damage from ground water. If the work is not commenced within the proper time, the Supervisor may appoint an agent to perform the work, the cost of which shall be paid from the petroleum and gas fund and shall constitute a lien against the property. Monthly reports are required by every producer of oil.

Before abandoning any well, the owner or operator shall shut off and exclude all water from entering oil-bearing or gas-bearing strata and shall use every effort to protect any underground or surface water suitable for irrigation or domestic purposes from the infiltration or addition of any detrimental substances. Also before abandoning any well, the owner or operator must give written notice of intention to abandon, at least five days before the proposed abandonment, showing the condition of the well and the proposed method of abandonment. The Supervisor, or the District Deputy, shall either approve the proposal, state what work or tests will be necessary before approval will be given, or state what information will be necessary before approval can be given. Within five days after completion of abandonment, the owner or operator shall make a report of work done, and thereafter the Supervisor or District Deputy shall furnish written final approval or a written disapproval setting forth the conditions upon which it is based.

Likewise, no person shall remove the casing or any portion thereof from any oil or gas well without first giving five days written notice to the Supervisor or the District Deputy of his intention to remove. The Supervisor or District Deputy shall give written approval or a written report stating what work shall be done before such approval will be given.

Procedure is also provided for ordering work to be done to correct complaints made by adjoining property owners. Also the Supervisor or District Deputy may order the abandonment of any well that has been deserted. Unreasonable waste of gas is prohibited. Violations of the act are a misdemeanor. Certain acts may also be enjoined.

The above provisions with respect to the regulation of oil and gas wells are in sharp contrast with the lack of state regulation concerning the drilling and operation of water wells, particularly prior to 1967 when the State assumed the authority to direct the adoption of well standards in critical areas.

Similar provisions for detailed regulation of geothermal resources wells are set forth in Public Resources Code, Division 3, Chapter 4, Sections 3700-3776. These provisions closely follow those governing the regulation of oil and gas wells. The State Oil and Gas Supervisor is charged with supervising the drilling, operation, maintenance, and abandonment of geothermal resources wells so as to encourage the greatest ultimate economic recovery of geothermal resources, and to prevent damage to, and waste from, the underground geothermal deposits, and to prevent damage to underground and surface waters suitable for irrigation or domestic purposes by reason of the drilling, operation, maintenance, and abandonment of geothermal resources wells.

Proposed Legislation

In considering the legal aspects of water well regulation, it may be of interest to consider legislation relative thereto which has been introduced but not enacted during the past few years. No attempt is made to include all such proposals, nor to review the proposals in detail, but simply to indicate the nature of the proposals. General scope of the proposals has been as follows:

(1) Authorize the appropriate regional water pollution control board to adopt minimum standards of construction, repair, and abandonment of water wells in accordance with recommendations by the Department of Water Resources. (AB 1514, 1516, 1951 Session.)

(2) Remove the one hundred dollars ($100.00) exemption from the contractors' license law. (AB 1949, 1955 Session, as amended June 2, 1955.)

(3) Require written notice to the appropriate regional water pollution control board of intention to undertake the work of construction, alteration, or abandonment of a water well,

and compliance with any construction standards for such well adopted by the regional board. (AB 1510, 1951 Session.)

(4) Make Section 7076 of the Water Code (report of well completion) applicable to every person who repairs or abandons a water well. (AB 1513, 1951 Session.)

(5) Provide for recordation of extractions of ground water from all areas of the State. (AB 2345, 1953 Session; AB 92, 1957 Session.)

(6) Include ground water in the statutory adjudication procedure. (AB 3097, 1949 Session; AB 1540, 1951 Session; AB 1033, 1955 Session.)

(7) Provide for a separate licensing board for water well drillers. (AB 1397, SB 350, 1949 Session; AB 1507, 1951 Session.)

(8) Require licensing of well drillers who are hired as "employees" but furnish all the equipment required for drilling a well. (AB 1508, 1951 Session.)

(9) Provide special procedure for adjudication of rights to use of ground water threatened by intrusion of natural saline waters. (AB 1515, 1951 Session.)

(10) Authorize regional water pollution control boards to establish minimum standards for construction, alteration or abandonment of wells in critical areas. (AB 1949, 1955 Session, as amended May 13, 1955.)

Regulation by Local Agencies

Mention has been made in this appendix of the regulatory powers of the State and the enactment in 1967 of legislation providing impetus from the State for the adoption by cities and counties of ordinances setting up well standards in local areas. Such ordinances may be adopted pursuant to the exercise of the local police powers. Section 11 of Article XI of the California Constitution provides: "Any county, city, town, or township may make and enforce within its limits all such local, police, sanitary, and other regulations as are not in conflict with general laws." (See 11 Cal. Jur. 2d 491, 531, Constitutional Law, Sections 126, 151.)

The police power vested in counties and municipalities by the above constitutional provision "is as broad as that vested in the Legislature itself, subject to the two conditions that enactments under it must be local to the county or municipality and must not conflict with general laws." (11 Cal. Jur. 2d 531.)

In regard to the point which might be raised as to whether a local ordinance conflicts with state law, it has been held that the mere fact that the State has by statute established regulations governing the subject does not prohibit local regulations establishing additional requirements not in conflict with general laws: In re Hoffman, 155 Cal. 114, 99 P. 517; Ex Parte Hong Shen, 98 Cal. 681, 33 P. 799; James v. Meyers, 68 Cal. App. 2d 23, 156 P. 2d 69; In re Iverson, 199 Cal. 582, 250 P. 681; Sawyer v. Napa County, 108 Cal. App. 446, 291 P. 892. Thus in the case of In re Maas, 219 Cal. 422, 27 P. 2d 373, the court held that a local ordinance designed to prevent waste of water pumped from the underground was a valid exercise by the county of the police power, and that although state law declares that all water within the State is the property of the people of the State, there was no conflict with state law.

Furthermore, state law specifically provides that no provision of Division 7 of the Water Code relating to water pollution and the control thereof by the State Water Resources Control Board and the regional water quality control boards, nor any ruling of the boards, is a limitation on the power of a city or county to adopt and enforce additional regulations not in conflict therewith imposing further conditions, restrictions, or limitations with respect to the disposal of sewage or other waste or any other activity which might result in the pollution of water, nor on the power of any city or county to declare, prohibit, and abate nuisances. (Water Code, Section 13001.) A similar provision is in Section 5415 of the Health and Safety Code, which likewise relates to regulation and control of sewage and other waste, but with emphasis on the powers of the Department of Public Health.

Under Water Code Sections 13800-13806, regional water quality control boards may require cities and counties to adopt satisfactory well standards, or may themselves adopt such standards for the area if the city or county fails to do so. Counties and cities may impose other or additional regulations as long as they do not directly conflict with the state requirements.

Because regulations of the nature herein discussed are within the police powers of counties and municipalities, specific statutory authorization to impose such regulations is not required. (In re Ackerman, 6 Cal. App. 5, 91 P. 429; People v. Velarde, 45 Cal. App. 520, 188 P.59; Merced Dredging Co. v. Merced County, 67 F. Supp. 598; 11 Cal. Jur. 2d 520, Constitutional Law, Sections 143-146.)

It has also been held that local agencies, such as cities and municipalities, may bring an action to abate a public nuisance, even where a regional water quality control board has prescribed requirements (<u>People v. City of Los Angeles</u>, 160 Cal. App. 2d 494, 325 P. 2d 639.)

APPENDIX E

SUGGESTED PROCEDURE FOR DISINFECTING WELLS

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SUGGESTED PROCEDURE FOR DISINFECTING WELLS

The procedure described in this appendix, is satisfactory for disinfecting a well; however, other methods may be used provided it can be demonstrated that they will yield comparable results.

1. The proper amount of chlorine solution, such that the concentration of chlorine in the well water shall be at least 50 parts per million (ppm) available chlorine, is added to the well. Table 5 lists quantities of various chlorine compounds required to dose 100 feet of water-filled casing at 50 ppm for diameters ranging from 2 to 24 inches.

2. The pump column or drop pipe shall be washed with the chlorine solution as it is lowered into the well.

3. After it has been placed into position, the pump shall be operated so as to thoroughly mix the disinfectant with the water in the well. Pump until the water discharged has the odor of chlorine. Repeat this procedure several times at one-hour intervals.

4. The well shall be allowed to stand without pumping for 24 hours.

5. The water shall then be pumped to waste until the odor or taste of chlorine is no longer detectable.

6. A bacteriological sample shall be taken and submitted to a laboratory for examination (See Appendix G).

7. If the laboratory analysis shows the water is not safe to use, the disinfection procedure should be repeated until the tests show the water is safe to use.

TABLE 5

CHLORINE COMPOUND REQUIRED TO DOSE 100 FEET OF WATER-FILLED CASING AT 50 PARTS PER MILLION

Diameter of Pipe or Casing (in inches)	Chlorine Compounds: (70%) HTH, Perchloron, etc. (Dry Weight)*	(25%) Chloride of Lime (Dry Weight)*	(5.25%) Purex Clorox, etc. (Liquid Measure)
2	1/4 ounce	1/2 ounce	2 ounces
4	1 ounce	2 ounces	9 ounces
6	2 ounces	4 ounces	20 ounces
8	3 ounces	7 ounces	2-1/8 pints
10	4 ounces	11 ounces	3-1/2 pints
12	6 ounces	1 pound	5 pints
16	10 ounces	1-3/4 pounds	1 gallon
20	1 pound	3 pounds	1-2/3 gallons
24	1-1/2 pounds	4 pounds	2-1/3 gallons

NOTE:

It is suggested that where wells to be treated are of unknown depth or volume, at least one pound of calcium hypochlorite (70% available chlorine) or two gallons of household bleach (sodium hypochorite) such as Clorox or Purex (5.25% chlorine) may be added in lieu of the use of the above table.

* Where a dry chemical is used it should be mixed with water to form a chlorine solution prior to placing it into the well.

APPENDIX F

SUGGESTED METHODS FOR SEALING THE UPPER PORTION OF THE ANNULAR SPACE AND FOR SEALING-OFF STRATA

APPENDIX F

SUGGESTED METHODS FOR SEALING THE UPPER PORTION OF THE ANNULAR SPACE AND FOR SEALING OFF STRATA

Following are listed several methods for sealing the upper portion of the annular space (the "sanitary seal") and for sealing off strata containing undesirable water. They are suggested methods only and are not a part of the standards for well construction presented in this report. There are, of course, other methods and variations to the methods described herein.

General

1. No drilling operations or other associated work in the well should be conducted for at least 12 hours, (some prefer 24 to 72 hours), after sealing operations have been completed.

2. Before installing or reinstalling the pump assembly, the well casing should be inspected and cleaned out if necessary.

3. Grout used in sealing should consist of one part of cement to five to six gallons of water (neat cement grout) per sack of cement or one or two parts of sand to one part of cement, and from five to seven gallons of water per sack of cement. Neat cement (cement and water only) is preferred over other grouts, as it eliminates the possibility of separation of sand and cement during placement. Additives, such as hydrated lime (up to 10 percent of the volume of cement) and bentonite (up to 5 percent) may be used.

Sealing the Upper Portion of the Annular Space

The following methods can be used to seal the upper portion of the annular space. The first method is the method most often used and appears to be the most successful.

Grouting Pipe Method. In this method, a seal is placed in the annular space from the bottom up through a grout pipe (similar to a tremie) suspended in the annular space.

1. Drill the hole large enough to accommodate the grout pipe (at least four inches greater in diameter than the diameter of the casing).

2. In caving formations install a conductor pipe.

3. Provide a grout retainer in the annular space below the interval to be sealed.

4. Extend the grouting pipe down the annular space between the casing and the wall or conductor pipe to the bottom of the interval to be sealed just above the retainer.

5. Add grout in one continuous operation, beginning at the bottom of the interval to be sealed at the same time pulling out the conductor pipe (if one is used). The grouting pipe should remain submerged in the sealing material during the entire time it is being placed.

If the annular space is restricted, it may be necessary to jet the grout pipe to the required depth. Quite frequently when a conductor casing is used, it is left in place. Where the annular space between the hole and the conductor casing and the conductor casing and inner casing are to be sealed, a common procedure is to place a five foot depth of grout into the hole, drive the conductor into the grout about one-half way, and pump grout into the annular space outside the conductor casing. Finally, upon installation of the inner casing, the annular space between the two casings is filled with grout.

Pressure Cap Method. In the pressure cap method, the grout is placed in the bottom of the hole through a grout pipe set inside the casing.

1. The casing or other inner pipe is suspended about two feet above the bottom of the drilled hole and filled with water.

2. A pressure cap is placed over the casing and grout pipe extended through the cap and casing to the bottom of the hole.

3. The grout is forced through the pipe, up into the annular space around the outside of the casing, to the ground surface.

4. When the grout has set, the plug formed during grouting is removed and drilling of the rest of the well is continued.

Dump Bailer Method. In the dump bailer method, the grouting is done with the hole drilled only slightly below the bottom of the casing and drilling is completed after the grout is in place and set.

1. Enough impervious grout is placed in the casing to fill the lower 20 to 40 feet of the hole by lowering a bailer filled with grout into the casing and opening the bottom valve which dumps the load of grout at the desired level.

2. The casing is raised 20 to 40 feet with the bottom of the casing remaining in the grout.

3. The casing is filled with water and capped, and the water-filled casing is then lowered to the bottom of the hole. This action should force the grout up the annular space between the casing and the drilled hole. The casing must remain capped until the grout is set. If it is anticipated that there will be difficulty in maneuvering the capped, water-filled casing, water can be put in on top of the grout without lifting the casing. Continue to add water to the casing until a quantity equal to the volume of grout has been put in. This should force most of the grout out of the lower end of the casing.

4. When the grout is set, drill through the hardened cement in the lower end of the casing and continue drilling the well.

Sealing-off Strata

The following methods can be used in sealing-off strata or zones.

The Pressure-Grouting Method. This method can be employed where an annular space exists between the well casing and the wall of the drilled hole.

1. Perforate the casing opposite the interval to be sealed.

2. Place a packer or other sealing device in the casing below the bottom of the perforated interval.

3. Place grout in the casing opposite the interval to be sealed by means of a dump bailer or grout pipe.

4. Place a packer or other sealing device in the casing above the perforations.

5. Apply pressure to the top packer to force the grout through the perforations into the interval to be sealed.

6. Maintain pressure until the material has set.

7. Drill out the packer and other material remaining in the well.

Frequently an assembly consisting of inflatable (balloon) packers and grout pipe is used. The packers are placed so as to enclose the interval to be sealed, they are inflated and the grout pumped down the hose (which passes through the upper packer) into interval to be sealed. Water is then pumped into the interval, squeezing the grout through the perforations. When the grout is sufficiently hardened the packers are deflated and removed.

Liner Method. Where an annular space does not exist between the well casing and the wall of the drilled hole, the liner method can be employed.

1. Place a smaller diameter metal liner (about two inches less in diameter) inside the casing opposite the perforated interval to be sealed, and extend it at least 10 feet above and below the perforated interval.

2. Provide a grout retaining seal at the bottom of the annular space between the liner and the well casing.

3. Extend the grouting pipe to the top of the opening between the liner and casing or connect it to the inside of the liner at the bottom via a tee (or other device), and fill the annular space between the well casing and the liner with grout in one continuous operation.

4. The grouting pipe should remain submerged in the sealing material during the entire time it is being placed.

APPENDIX G

COLLECTION OF WATER QUALITY SAMPLES

APPENDIX G
COLLECTION OF WATER QUALITY SAMPLES

Bacterial Sampling

Sampling of community water supply wells, is covered by requirements of the State Board of Health and the local health department. For individual domestic wells, technical assistance or advice regarding the collection of bacteriological samples may be obtained from the local health department or from the laboratory that will examine the sample.

If no technical assistance is available, the following procedure will suffice: A sterile sample bottle, preferably one provided by the laboratory that will make the determination, must be used. It is extremely important that nothing except the water to be analyzed come in contact with the inside of the bottle or the cap; the water must not be allowed to flow over an object or over the hands while the bottle is being filled. Do not rinse the sample bottle. The sample should be delivered to the laboratory as soon as possible and in no case more than 24 hours after its collection. During delivery, the sample should be kept as cool as possible (but not frozen).

Chemical (Mineral) Sampling

Generally, a routine mineral analyses (determination of the concentrations of the common minerals) will suffice, particularly where there is no prior knowledge of the chemical quality of the water in the area where the well is located. Where quality conditions in the surrounding area are known, a more selective analysis may be made. For certain uses it may also be desirable to make analysis for concentrations of the heavy metals (such as iron and manganese in the case of domestic water) or other constituents not routinely determined. Information or advice on chemical quality conditions may be obtained from local agencies such as the county farm advisor's office, health department, and water service agency (irrigation or water district, for example).

The sample should be collected after the well has been pumped long enough to remove standing water and development and disinfectant chemicals, and to insure that water from the producing formation(s) has entered the well. The water sample should be obtained in a chemically clean container preferably one obtained from the laboratory which has been selected to perform the analysis. The container should be rinsed several times with the water to be sampled prior to collecting the sample. The laboratory performing the analysis should issue instructions regarding the quantity of sample required. However, one-half gallon is usually sufficient for a routine mineral analysis; one gallon when analysis for heavy metals is also required.

APPENDIX H

WATER QUALITY CRITERIA

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WATER QUALITY CRITERIA

Criteria presented in the following sections can be used in evaluating the quality of water relative to existing or anticipated beneficial uses. It should be noted that these criteria are merely guides to the appraisal of water quality. Except for those constituents which are considered toxic to human beings, these criteria should be considered as suggested limiting values. A water which exceeds one or more of these limiting values need not be eliminated from consideration as a source of supply, but other sources of better quality water should be investigated.

For a thorough review of this subject and for detailed information regarding specific substances and uses, the reader is referred to "Water Quality Criteria" Second Edition, 1963, Publication No. 3-A of the State Water Quality Control Board.

Domestic and Municipal Water Supply

In general, water that is used for drinking or culinary purposes should be clear, colorless, odorless, pleasant to the taste, and free from toxic compounds. It should not contain excessive quantities of dissolved minerals, and must be free from pathogenic organisms.

Division 5 of the California Health and Safety Code contains provisions which relate to water supplies used for domestic purposes throughout the State. One of these provisions covers standards for quality of domestic water supplies. In essence, this section (No. 4010.5) refers to the drinking water standards promulgated by the U. S. Public Health Service for water used on interstate carriers as of March 1946.

In 1962, the U. S. Public Health Service revised (updated) its drinking water standards to take cognizance of man's changing environment and its effect on water supplies. Portions of these new standards are presented herein. The complete standards, which cover definition of terms, bacteriological quality, physical characteristics, chemical characteristics, radioactivity, and recommended analytical methods, are described in publication No. 956 of the U. S. Department of Health, Education, and Welfare, Public Health Service, "Public Health Service Drinking Water Standards 1962".

Mineral Concentrations. The following tabulation gives the limiting concentrations of chemical constituents for drinking water, as prescribed by the U. S. Public Health Service.

UNITED STATES PUBLIC HEALTH SERVICE
DRINKING WATER STANDARDS 1962

Constituent	Mandatory limit in ppm
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Hexavalent chromium (Cr^{+6})	0.05
Cyanide (CN)	0.2
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

Constituent	Nonmandatory, but recommended limit in ppm
Alkyl benzene sulphonate (detergent)	0.5
Arsenic (As)	0.01
Carbon chloroform extract (exotic organic chemicals)	0.2
Chloride (Cl)	250
Copper (Cu)	1.0
Cyanide (CN)	0.01
Fluoride (F)	See following page
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate (NO_3)	45
Phenols	0.001
Sulfate (SO_4)	250
Total dissolved solids	500
Zinc (Zn)	5

Interim standards for the upper limits of certain mineral constituents were adopted by the California State Board of Public Health in December 1959. Based on these standards, temporary permits may be issued for drinking water failing to meet the U. S. Public Health Service Drinking Water Standards, provided the mineral constituents in the following tabulation are not exceeded.

UPPER LIMITS OF TOTAL SOLIDS AND SELECTED MINERALS IN DRINKING WATER AS DELIVERED TO THE CONSUMER
(parts per million)

	Permit	Temporary Permit
Total Solids	500 (1000)*	1500
Sulfates (SO_4)	250 (500)*	600
Chlorides (Cl)	250 (500)*	600
Magnesium (Mg)	125 (125)*	150

Fluoride Concentration. The California State Board of Public Health has defined the maximum safe amounts of fluoride ion in drinking water in relation to mean annual temperature.

Mean annual temperature	Mean monthly fluoride ion concentration (ppm)
50° F	1.5
60° F	1.0
70° F and above	0.7

Hardness. Even though hardness of water is not included in the drinking water standards, it is of importance in domestic and industrial uses. Excessive hardness in water used for domestic purposes causes increased consumption of soap and formation of scale in pipes and fixtures. The following tabulation for degrees of hardness is suggested.

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* Numbers in parentheses are maximum permissible to be used only where no other more suitable waters are available in sufficient quantity for use in the system.

Range of hardness expressed as $CaCO_3$, in ppm	Relative classification
0 - 100	Soft
101 - 200	Moderately hard
Greater than 200	Very hard

Radioactivity. As part of its 1962 drinking water standards, the U. S. Public Health Service announced limits on concentrations of radioactivity in drinking waters. These limits are as follows:

Radionuclide	Recommended maximum limits micromicrocuries per liter
Radium 226	3
Strontium 90	10
Gross beta activity	1000*

Industrial Water Supply

Water quality criteria for industrial waters are as varied and diversified as industry itself. Food processing, beverage production, pulp and paper manufacturing, and textile industries have exacting requirements. However, many cooling or metallurgical operations permit the use of poor quality water. In general, where a water supply meets drinking water standards, it is satisfactory for industrial use, either directly or following a limited amount of polishing treatment by the industry.

Irrigation Water

Criteria for mineral quality of irrigation water have been developed by the Regional Salinity Laboratories of the U. S. Department of Agriculture in cooperation with the University of California. Because of diverse climatological conditions and the variation in crops and soils in California, only general limits of quality for irrigation waters can be suggested.

* In the known absence of strontium-90 and alpha emitters.

QUALITATIVE CLASSIFICATION OF IRRIGATION WATERS

Chemical properties	Class 1 Excellent to good	Class 2 Good to injurious	Class 3 Injurious to unsatisfactory
Total dissolved solids, in ppm	Less than 700	700 - 2000	More than 2000
Conductance, in micromhos at 25° C	Less than 1000	1000 - 3000	More than 3000
Chlorides in ppm	Less than 175	175 - 350	More than 350
Sodium in percent of base constituents	Less than 60	60 - 75	More than 75
Boron in ppm	Less than 0.5	0.5 - 2.0	More than 2.0

These criteria have limitations in actual practice. In many instances a water may be wholly unsuitable for irrigation under certain conditions of use, and yet be completely satisfactory under other circumstances. Consideration also should be given to soil permeability, drainage, temperature, humidity, rainfall, and other conditions that can alter the response of a crop to a particular quality of water.

APPENDIX I

DEFINITION OF TERMS

APPENDIX I

DEFINITION OF TERMS

The following terms are defined as used in this report:

Abandoned Well--A well whose original purpose and use has been permanently discontinued or which is in such a state of disrepair that its original purpose cannot be reasonably achieved.

Active Well--An operating water well.

Annular Space--The space between two well casings or a well casing and the wall of the drilled hole.

Aquifer- A formation or group of formations or part of a formation that is water bearing, and which transmits water in sufficient quantity to supply pumping wells.

Bailer--A long narrow bucket made of pipe with a valve in the bottom used to remove cuttings from the hole.

Casing--A tubular retaining structure, generally metal, which is installed in the excavated hole to maintain the well opening.

Clay--A fine-grained inorganic material (grains less than 0.005 mm in diameter) which has very low permeability and is plastic.

Conductor Pipe or Casing--A tubular retaining structure installed between the drilled hole and the inner casing, in the upper portion of a well.

Cone of Depression--The depression, roughly conical in shape, produced in a water table or piezometric surface by pumping (or artesian flow).

Confined Ground Water-- A body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with all overlying ground water except at the upper edge of the confining stratum where the confined water connects with free ground water. Confined ground water moves in strata, conduits or arteries under the control of the difference in head between the intake and discharge areas of the confined water body.

Connate Water--Water entrapped in the interstices of a sedimentary rock at the time it was deposited. These waters may be fresh, brackish, or saline in character. Because of the dynamic geologic and hydrologic conditions in California, this definition has been altered in practice to apply to water in older formations, even though the water in these formations may have been altered in quality since the rock was originally deposited.

Contamination--Defined in Section 13005 of the California Water Code: "An impairment of the quality of the waters of the State by sewage or other waste to a degree which creates an actual hazard to public health through poisoning or through the spread of disease...." Jurisdiction over matters regarding contamination rests with the State Department of Public Health and local health officers.

Degradation--Impairment in the quality of water due to causes other than disposal of sewage and other waste.

Destroyed Well--A well that has been filled or plugged so that it will not produce water nor act as a conduit for the movement of water.

Deterioration--An impairment of water quality.

Drilled Well--A well for which the hole is generally excavated by mechanical means such as the rotary or cable tool methods.

Driller's Mud--A fluid composed of water and clay (Either native clay or combination with commercial clays) used in the drilling (primarily rotary) operation to remove cuttings from the hole, to clean and cool the bit, to reduce friction between the drill stem and the sides of the hole, and to plaster the sides of the hole. Such fluids range from relatively clear water to carefully prepared mixtures of special purpose compounds.

Drive Shoe--A forged steel collar with a cutting edge fastened onto the bottom of casing to shear off irregularities in the hole as the casing advances, and to protect the lower edge of the casing as it is driven.

Free Ground Water--Water moving through an interconnected body of pervious material unhampered by impervious confining material, and moving under control of the water table slope.

Gravel Packed Well--A well in which gravel is placed in the annular space to increase the effective diameter of the wall, and to prevent fine-grained sediments from entering the well.

Ground Water--That part of the subsurface water which is in the zone of saturation.

Ground Water Basin--A ground water basin consists of an area underlain by permeable materials which are capable of furnishing a significant water supply; the basin includes both the surface area and the permeable materials beneath it.

Grout--A fluid mixture of cement and water (neat cement) of a consistency that can be forced through a pipe and placed as required. Various additives, such as sand, bentonite, and hydrated lime, are included in the mixture to meet certain requirements. For example, sand is added when a considerable volume of grout is needed.

Impairment--A change in quality of water which makes it less suitable for beneficial use.

Impermeable--Having a texture that does not permit water to move through it perceptibly under the head differences ordinarily found in subsurface water.

Impervious Stratum--A formation, group of formations, or part of a formation which, although often capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for wells or springs.

Inactive or Standby Well--A well not operating but capable of being made an operating well with a minimum of effort.

Other Waste--Defined in Section 13005 of the California Water Code: "any and all liquid or solid waste substance, not sewage, from any producing, manufacturing or processing operation of whatever nature".

Packer--A device placed in a well which plugs or seals the well at a specific point.

Perforations--A series of openings in a well casing, made either before or after installation of the casing, to permit the entrance of water into the casing.

Permeability--The permeability (or perviousness) of a material is its capacity for transmitting a fluid. Degree of permeability depends upon the size and shape of the pores, the size and shape of their interconnections, and the extent of the latter.

Pollution--Defined in Section 13005 of the California Water Code: "an impairment of the quality of the waters of the State by sewage or other waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, industrial, agricultural, navigational, recreational, or other beneficial use, or which does adversely and unreasonably affect the ocean waters and bays of the State devoted to public recreation". Regional Water Quality Control Boards are responsible for prevention and abatement of pollution.

Pressure Grouting--A method of forcing impervious grout into specific portions of a well, such as the annular space, for sealing purposes.

Puddled Clay--Clay or a mixture of clay and sand, kneaded or worked when wet to render it impervious to water.

Sewage--Defined in Section 13005 of the California Water Code: "any and all waste substance, liquid or solid, associated with human habitation, or which contains or may be contaminated with human or animal excreta or excrement, offal, or any feculent matter". As used in this report, sewage is included as part of the waste waters carried by community sewer systems.

APPENDIX J

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APPENDIX J

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