California of widespread water quality deterioration are in coastal ground water basins that have been subjected to seawater intrusion.

Inadequately constructed or improperly "abandoned" wells are not the sole cause of water quality degradation in a California ground water basin. A small quantity of contaminants entering one well may not have far-reaching effect. However, (1) the construction of thousands of new wells in California each year, (2) the fact that many are becoming more closely spaced, and (3) the growing number of wells being neglected or indiscriminately abandoned indicate that the potential for impairing ground water quality is growing. Then, when pollutants move along the lines of natural water movement, the effects will be long-lasting and difficult, if not impossible, to correct.

Inadequately constructed or improperly destroyed wells facilitate the impairment of ground water quality (see Figures 1 and 2) in five principal ways:

1. When the well is located too close to sources of pollution or contamination or downstream from them so that the well can be directly affected by flow from these sources (Figure 1A). Ironically, sometimes the source of pollution is a nearby abandoned well.

2. When the surface portion of the well is constructed without protective features so that contaminated or polluted waters can flow directly into the well through one or more of several possible openings in or under the pump. Usually under these circumstances only the water in or adjacent to the well is affected (Figure 1B and 1C).

3. When the annular space (the space between the outside of the casing and the wall of the hole) lacks an adequate vertical seal and surface water or shallow subsurface water flows into the well along the outside of the casing. (Note that although the annular space may be filled with granular filter material, i.e., the familar "gravel-pack", no seal exists and undesirable water can move downward or laterally.) This type of defective well is particularly susceptible (Figure 1D) to contamination.

4. When, during well construction (or the destruction of abandoned wells), aquifers that produce poor quality water are ineffectively sealed off, allowing the interchange of water with one or more aquifers and thus significantly impairing the quality of water in those aquifers. The well now provides a physical connection between these aquifers (Figure 2).

5. When the well is used intentionally, accidentally, or carelessly for the disposal of waste allowing direct contamination of the ground water to occur. Such disposal is prohibited by law except under specially approved circumstances.

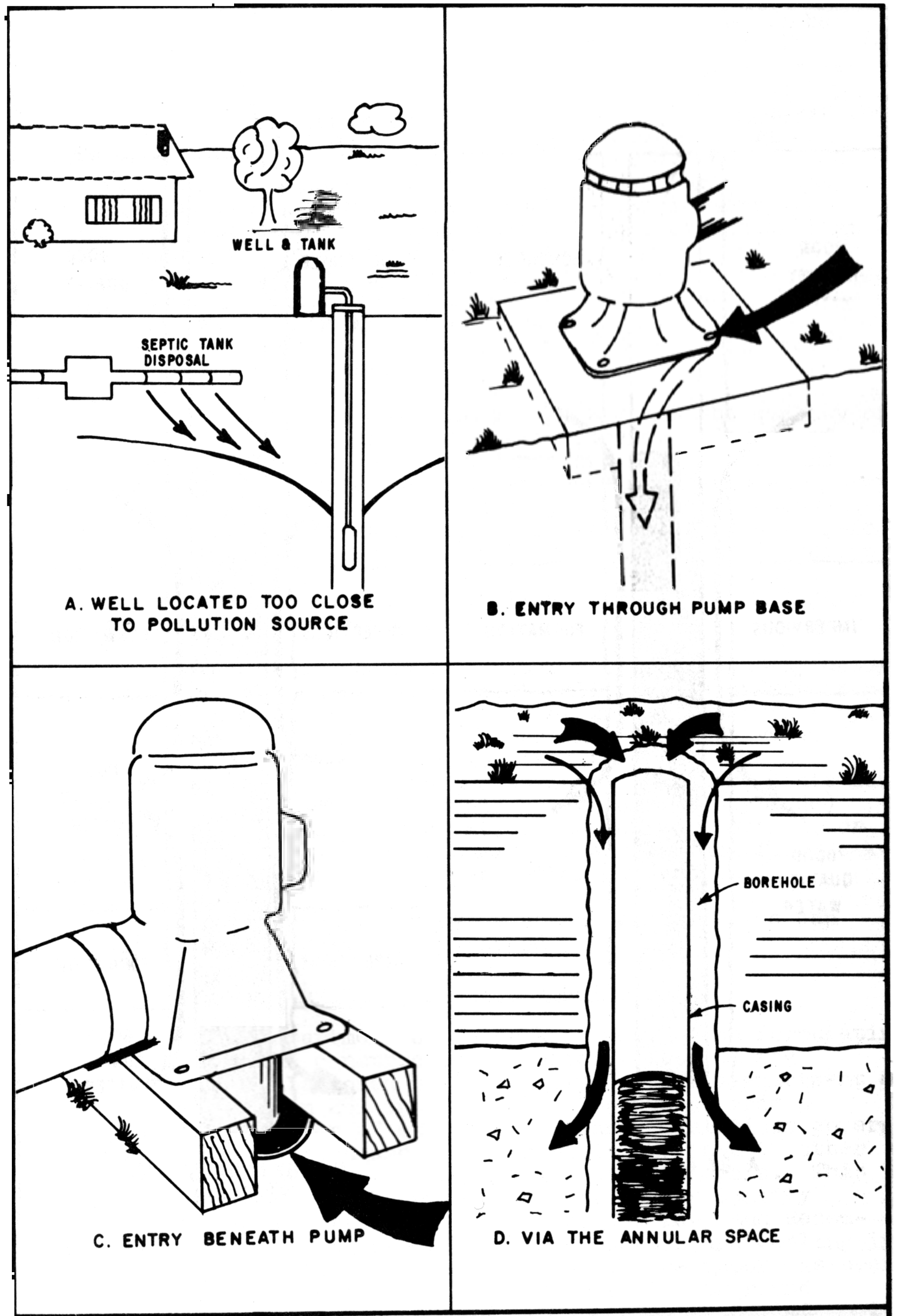

Figure 1. AVENUES OF ENTRANCE FOR POLLUTANTS TO WELLS

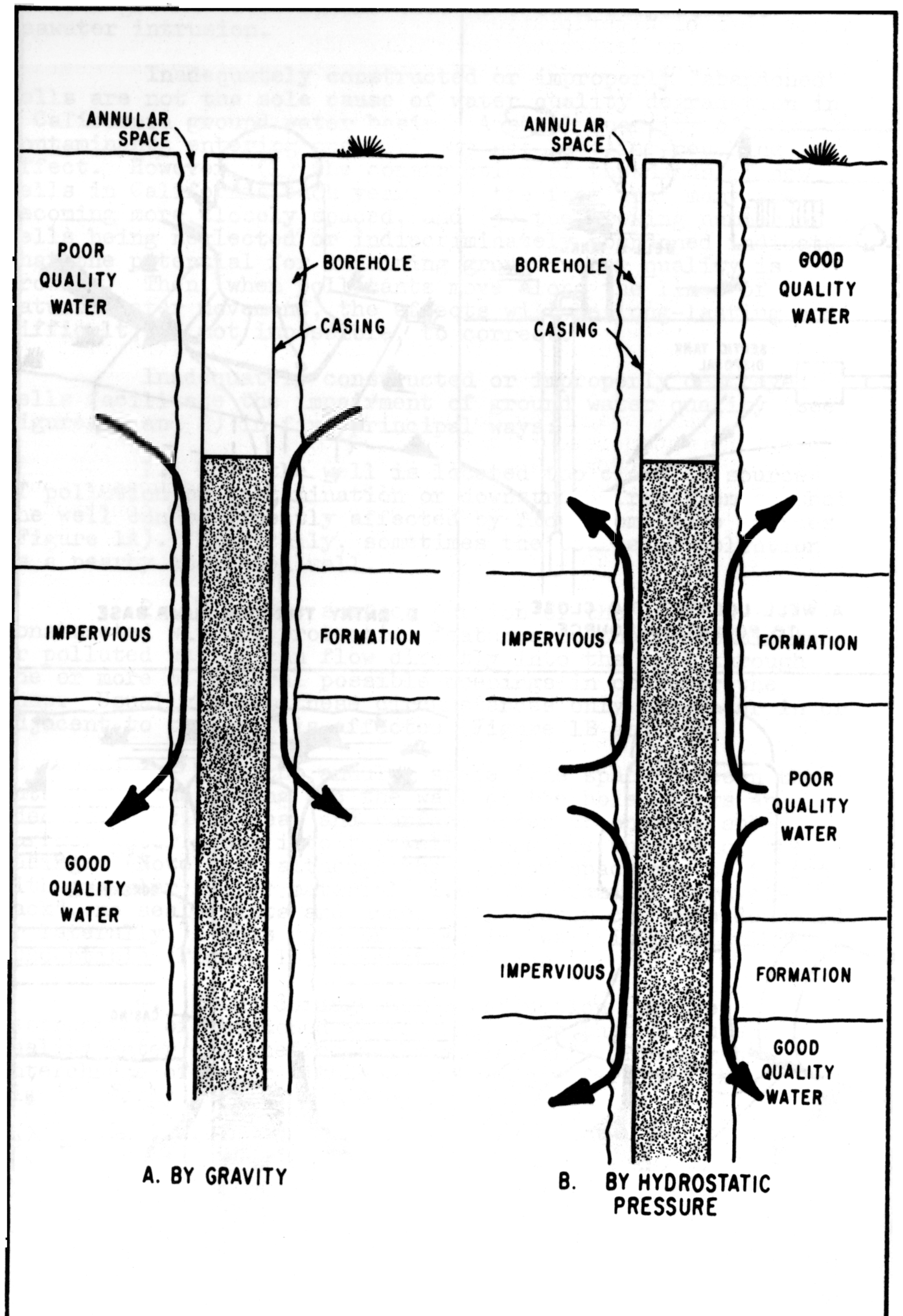

Figure 2. INTERCHANGE OF WATER BETWEEN FORMATIONS VIA WELLS

Irrespective of the probability of occurrence and which form of deterioration takes place, wells should be constructed or destroyed such that they do not contribute to the impairment of the quality of California's ground water supplies. Moreover, while the well construction industry, advisory groups, and regulatory agencies want to protect the quality of the State's ground water supplies as well as assure that wells are adequately constructed, there is no broad, uniform approach for so doing in California. The resolution of this problem requires the development of standards for water well construction and destruction that will ensure the protection of the State's ground waters as they exist in the ground or as they pass through the well for use. Such 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 well owner.

Well standards do more than protect the quality of the ground water resource; they also provide a degree of consumer protection. When standards are established and implemented in an area, well owners have more assurance that their wells will be constructed properly. Proper construction could mean less maintenance with an extended well life. Most well owners do not realize that deficiencies in design and construction (including failure to close-off access to pollutants described above) are likely to result in higher operating and maintenance costs.

A subject touched upon earlier is the safety hazard posed by the unused or "abandoned" well. While safety is not a matter involving the maintenance of ground water quality, it should be a concern to all those involved with water wells. Any abandoned excavation is a threat to the safety of people, especially children and animals. Further, State law (Section 24400 of the California Health and Safety Code) requires that abandoned excavations be fenced, covered, or filled. Yet, children (and sometimes adults) and livestock do fall into abandoned wells and other excavations.

By properly destroying abandoned wells, we can easily eliminate this safety hazard.

Developing the Standards

The Department of Water Resources began formulating standards for the construction of water wells and the destruction of abandoned wells shortly after the enactment of Water Code Section 231 in 1949. The Department made 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. Although the report is over 25 years old, it remains a useful source of background information. The Department has continued to keep informed of practices in other states, particularly those in which standards have been established, and changes in the status of California county well ordinances.

Concurrently the Department assembled and evaluated information on the development of well standards in California. The information was grouped into three broad categories: (1) ground water geology and hydrology, (2) impairment of ground water quality, and (3) water well construction practices. The latter included suggestions and recommendations on methods and materials from representatives of state and federal agencies, steel companies, casing fabricators, pump manufacturers, water well drilling contractors, and other organizations and individuals concerned with the development and use of ground water.

This activity culminated in the publication of the standards in their initial draft form, "Recommended Minimum Well Construction and Sealing Standards for Protection of Ground Water Quality State of California", Bulletin 74, Preliminary Edition, July 1962. In March and April 1965, the Department conducted a series of public hearings in conjunction with the Department of Health Services at six cities in the State. Discussion and comments received centered on two areas: (1) the standards recommended, and (2) means of implementation. Most of those concerned felt that the standards, as written, were too general. Accordingly, the Department decided to redraft them.

Following a review of all prior material and comments received during the period 1963 through 1966, the Department published an interim edition of the chapter containing the standards in February 1967. Two public 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 Health Services.

The eight hearings produced correspondence and an extensive file of transcripts containing information, opinions, and suggestions, which would fill several volumes, if published.

In February 1968 standards ed in their current form.

For the most part, the standards can be applied anywhere in the State under practically any conditions. The procedures for closing-off the avenues of access, properly locating a well, destroying an abandoned well, etc., in Del Norte County, at the northwest corner of California, are similar to those in western Fresno County. Similarly, sealing-off the water in one or more zones or aquifers, to prevent its migration to other zones or aquifers, may be just as desirable for a well in western Merced County as it is at one on the Oxnard plain of Ventura County although, perhaps, for different reasons. However, in specific areas of the State it has been necessary to define the existing geologic and hydrologic conditions and the circumstances under which these standards should be applied. For example, it is helpful to describe the areal and vertical extent of geologic materials where sealing is needed to prevent the migration of poor quality water.

Thus, the Department maintained a concurrent and subsequent activity consisting of studies and reports describing the application of standards in designated areas of California. And, in addition to Bulletin 74, the Department issued a number of reports containing well standards for those areas (see Table 1).1/

The 1981 Edition

The foreword to the 1968 edition stated that:

> "Whereas the standards 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 degree of success achieved in their application."

Sufficient changes in the field of water well construction and experience with applying the 1968 standards warrant revising them. Foremost among the changes in construction practices are:

1. The development and use of plastic materials for casing in water wells. A subject only alluded to in the 1968 edition, the use of plastic well casing and screen has had phenomenal growth in the United States. So much has the usage increased that a national materials standard has been developed and a manual of installation practices has just been published.

2. The use of the air rotary drilling method for constructing wells in the hard rock areas of the State. Although this method of drilling was in use in 1968, its use has mushroomed since then. The equipment is very effective and very fast. Coupled with the use of plastic well casing, the method has made the construction of a well several hundred feet deep in one day a common event in hard rock areas.

3. Rapid growth in the use of well screens in place of perforated casing in the intake sections of wells.

4. Increased use of the reverse-circulation method of well drilling for large diameter deep wells in unconsolidated formations. It too is an extremely fast method.

1/ One other report, Bulletin 74-1, "Cathodic Protection Well Standards: State of California", March 1973 deals with another kind of well. Cathodic protection wells house devices used to alleviate electrolytic corrosion of pipelines, tanks, and similar installations. Such wells may also function as instruments for the deterioration of ground water quality. For that reason, standards for their construction and destruction have also been issued.

TABLE 1
REPORTS ISSUED UNDER
WATER WELL STANDARDS PROGRAM 1/

Area of Study	DWR Bulletin No.	Publication Date 2/ 3/
Mendocino County	62	November 1958 Supplement 8/7/69 4/
Alameda County	74-2	P.E. December 1962 F.E. June 1964 Supplement 10/20/69 4/
Del Norte County	74-3	P.E. March 1964 F.E. August 1966
Central, Hollywood and Santa Monica Basins (Los Angeles County)	74-4	October 1965 Final Supplement August 1968
San Joaquin County	74-5	March 1965 Final Supplement July 1969
Fresno County	74-6	September 1968
Arroyo Grande Basin (San Luis Obispo Co.)	74-7	July 1971
Shasta County	74-8	August 1968
Ventura County	74-9	August 1968
West Coast Basin (Los Angeles County)	107	August 1962 Supplement 8/16/68 4/
Coachella Valley Area (Riverside County)	5/	August 1979

1/ Listed by DWR Bulletin Number.
2/ Publications issued prior to June 1971 are out-of-print. Copies may be borrowed or inspected at Department's district offices, county offices administering well ordinances and local libraries.
3/ P.E. - Preliminary Edition; F.E. - Final Edition.
4/ Following the enactment of Sections 13800 through 13806 of the Water Code in 1967 supplemental memoranda reports summarizing the material presented in these publications and recommending the establishment of standards in these areas were issued.
5/ Unnumbered memorandum report.

Other factors include:

1. Population growth in the hilly and mountainous rural areas of California, which has resulted in a heavy demand for individual and community water supplies in those areas.

2. The 1976-77 drought, the most severe in a half-century, which caused a heavy demand for new wells, replacement wells, and well deepenings. It also produced an increased awareness of the significance of the State's ground water resources.

3. The increasing cost of energy for pumping. In terms of well construction and operation, this has meant greater interest in the design of efficient wells and in well maintenance (previously, a much neglected activity).

These as well as other considerations led to the decision to revise the 1968 edition.

This edition is composed of this chapter, Chapter II, "Standards", and five appendixes.

While there have been a number of modifications and additions to them, the 23 sections of Chapter II, "Standards", are as listed in the 1968 edition. All references to existing laws, standards, and publications have been updated and, where appropriate, additional explanation is provided. Every effort has been made to clarify wording to ensure its understanding. A number of figures illustrating the standards have been included.

Many technical terms concerning ground water and water well construction are frequently misunderstood or 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. In this report, we have tried to ensure that the technical terms used are understandable.

A list of definitions appears in Appendix A. Certain definitions are made a part of the standards and are presented in Chapter II. Appendixes B, C, and D describe sealing methods, disinfection, and water quality sampling respectively.

Numerous publications relating to the construction of water wells and to the development, use, and protection of ground waters have been reviewed in preparation of this report. Included is a considerable body of literature on well construction that has been written since 1968. They are listed in Appendix E in alphabetical order by author.

Establishing and Enforcing Standards

Authority for establishing and enforcing standards for construction and destruction of water wells has always rested with the 58 counties and 429 cities in California.

Where public water supplies are concerned, additional requirements may be prescribed by the Department of Health Services. Prior to the release of the 1968 edition of this report, only three counties and a few cities had adopted ordinances regulating the construction of water wells. In 1967, legislation was enacted authorizing the State (through the California Regional Water Quality Control Boards) to require cities and counties to adopt satisfactory ordinances governing well standards in critical areas. If they did not, the State would adopt such ordinances for the cities and counties. (This procedure is outlined in Sections 13800 through 13806 of the Water Code.)

Today, 33 counties have well ordinances establishing standards for the construction of all wells within their boundaries. They are listed in Table 2. Six other counties have adopted ordinances that deal with specific kinds of wells or conditions (as, for example, individual domestic wells only). While this latter group of ordinances provides protection for the users of water from the specified wells in these areas, they do little to protect the quality of the ground water resource (in contrast with the 33 counties listed in Table 2). Table 3 lists the six counties with ordinances for specific kinds of wells. Thirty-four of the total of 39 county ordinances specify the standards presented in the 1968 edition, with modifications where appropriate (all of which are more stringent than those in the 1968 edition).

One-third of the 429 cities in California have also adopted well ordinances. Many cities have working arrangements or agreements with county governments so it is difficult to state the exact number of cities employing well construction standards. Cities with ordinances are situated in the following counties (number of cities with ordinances in parenthesis):

Alameda (4)	Orange (26)	San Joaquin (6)
Fresno (8)	Placer (1)	San Luis Obispo (6)
Kern (1)	Riverside (1)	San Mateo (5)
Los Angeles (51)	Sacramento (1)	Santa Barbara (2)
Merced (3)	San Bernardino (1)	Stanislaus (1)
Nevada (1)	San Diego (10)1/	Sutter (1)
		Ventura (9)

1/ Since it has no ground water resource, the eleventh city in San Diego County, Coronado, has no ordinance.

TABLE 2
COUNTY ORDINANCES IN CALIFORNIA
CONCERNING THE CONSTRUCTION AND DESTRUCTION OF WELLS
(As of December 1981)

County	Ordinance Number	Date Adopted	Remarks
Alameda	73-68	7/17/73	
Butte	1845	8/2/77	
Contra Costa	1189	1/14/58	
Del Norte	73-30	11/12/73	
Fresno	470-A-39	10/22/74	
Humboldt	897	12/21/72	
Inyo	309	10/4/76	
Kings	365	1/13/76	
Los Angeles	10075	9/1/70	
Madera	412	3/16/76	
Mariposa	373	9/18/73	
Mendocino	1135	8/28/73	
Merced	752	6/10/75	
Mono	75-459	8/26/75	
Monterey	1967	5/29/73	
Napa	335	12/1/70	
Orange	2607	7/18/72	
Placer	1498B	5/9/72	Amended 1977, 1981
Sacramento	508	10/26/55	
San Bernardino	1954	10/15/74	
San Diego	4286	4/3/74	
San Joaquin	1862	12/21/71	
San Luis Obispo	1271	5/7/73	
San Mateo 1/	2413	1/11/77	
Santa Barbara	2769	9/29/75	
Santa Clara 2/	75-6	10/14/75	Ordinance of the Santa Clara Valley Water Dist.
Santa Cruz	1577	2/16/71	
Shasta	479	6/30/69	
Sonoma	1594	12/18/72	
Stanislaus	NS443	6/5/73	
Tulare	1758	8/13/74	Amended 4/16/76
Ventura	2372	8/31/70	Amended 10/1/79
Yolo	765	9/7/76	

1/ Predecessor ordinance numbers 1100 (12/15/55) and 2324 (7/8/75).
2/ Separate ordinance for subdivision wells - NS1203.22 (4/21/64).

TABLE 3
COUNTY ORDINANCES IN CALIFORNIA
WITH LIMITED APPLICATION TO WELLS
(As of December 1981)

County	Ordinance Number	Date Adopted	Application
Kern	G1225	12/16/69	Community water supply wells
	G3321	9/21/81	Agricultural wells
Marin	1463	1965	Domestic water supply
Plumas	786	5/15/73	Domestic wells only
Riverside	340A	5/3/48 1/	Provisions concern permit
San Francisco	659	1952	Individual domestic wells only
Sierra	420	5/7/74	Well construction only

1/ Amended December 1, 1952 and December 23, 1957.

Design and Performance Guidelines

While the standards presented here (see Chapter II following) are designed to protect the continued utility of the State's ground water resources, they are only incidently related to the effective use of these resources. Events of the past decade have emphasized the need for conservation of water and energy. Furthermore, consumers (in this case, well owners) have become more aware of problems resulting from inefficient operation (as reflected in increased energy consumption) and inadequate maintenance.

Accordingly, this section was prepared to provide well owners and drillers with guidelines for measuring performance that will lead to the design and construction of more efficient wells as well as those requiring less maintenance.

Testing for Capacity

Every well owner is interested in how much water the well will produce and how dependable the production will be with time. To make that determination a capacity test or performance test must be made. Usually this involves installing a pump and operating it at the expected production rate over a certain length of time. There is considerable variation in actual practice on how such tests are performed depending on the dimensions of the well, including expected capacity and intended use as well as geologic conditions at the site. Obviously, for a small capacity well, i.e., one that produces under 50 gallons (190 litres) per minute, the test would not be as elaborate as it would be for a high capacity well but is no less important.

The amount of water needed is determined by the intended use of the water. For example, on the average, each person in a household uses 100 gallons (380 litres) of water a day. To the daily household use must be added seasonal uses such as lawn and garden irrigation, swimming pools, etc. Table 4 lists the volume of water supplied from a small capacity well, assuming continuous pumping for 24 hours. Thus, a well supplying one to three gallons (4 to 11 litres) per minute is a reasonable amount for a single family dwelling. Additional amounts, such as for watering livestock or irrigating small acreages of crops, must be added to these values. Table 4 also indicates that a family of four could subsist on the water supplied by a well pumping constantly at the rate of only one-quarter gallon (0.95 litre) per minute. Unfortunately, at this rate there is little margin for error.

Small Capacity Wells. Performance tests for small capacity wells are relatively simple. A widely used test for small capacity wells is a pump test which lasts for four hours or until an apparently stable pumping level has been achieved at a rate equal to that expected for the permanent pump. However, in the hilly and mountainous "hard rock" areas of the State there are no defined aquifers and supplies are related to fracture patterns, the nature and extent of the soil mantle, faults, changes in stratigraphy, etc. In such areas the production potential of a well cannot be accurately assessed. Further, wells in these areas often exhibit a satisfactory initial production, which then declines due to poor recharge characteristics of the surrounding material. In such situations a longer than usual test, upwards of 12 to 24 hours (and longer) duration, may be desirable.

Bailing or air-blow tests give an approximate indication of production. They do not provide information of the accuracy needed to determine well capacity or to design an efficient pump system. (Air lift testing differs from air-blow testing. It involves pumping with air, not blowing the water out of the well as is the case with the air-blow test.)

The ability of the water level in a small capacity well to recover should be observed. If the water level fails to return to nearly its original level after 24-hours, the reliability of the producing zone is open to question.

Large Capacity Wells. Where large capacity wells are concerned, capacity tests are more elaborate and extensive. Such wells are usually located in defined, productive ground water basins, where considerable information on existing conditions is normally available to aid in the evaluation of their performance. All should be pump tested; bailer tests are of little value. The test pump should be capable of pumping 125 percent of the desired yield of the well. Pumping should be continued at a uniform rate until the "cone of depression" reflects any boundary condition that could affect the performance of the well. This could be as short as six hours and as long as several days, depending on aquifer characteristics and knowledge

TABLE 4
VOLUME OF WATER PUMPED CONTINUOUSLY
FROM SMALL CAPACITY WELLS

Pumping Rate		Total Pumped in 24-Hours	
Gallons (litres) per minute		Gallons	Litres
0.25	(1)	360	1 360
0.5	(2)	720	2 720
1	(4)	1,440	5 450
2	(8)	2,900	11 000
3	(11)	4,300	16 300
5	(19)	7,200	27,200
10	(38)	14,400	54 500
50	(190)	72,000	273 000

of the aquifer(s) in which the well is situated. The discharge rate and drawdown established should be maintained for a specified time period. The ratio of the discharge rate to the drawdown is called the specific capacity of the well for that time period. The units for specific capacity are gallons per minute per foot (litres per minute per metre) of drawdown. Static water levels must be measured in advance of the test and after the test during recovery.

Detailed descriptions of procedures and methods used in conducting pump tests for large capacity wells and for analyzing and interpreting the results are too lengthy to be included in this publication. Such information will be found in literature on ground water and on the design of water wells.

Well Efficiency

Well efficiency is defined as the ratio of the theoretical drawdown in the formation to the actual drawdown in the well. The difference between the two is caused by frictional energy losses of the water as it moves from within the formation to the pump intake. Thus, well efficiency describes the effectiveness of a well in yielding water. Well efficiency should not be confused with pumping-plant (motor and pump) or "wire-to-water" efficiency used to measure pumping-plant performance.

It should be obvious that well efficiency is related to the cost of pumping and the use of energy. If efficiency improves, pumping costs and energy consumption will drop. Thus, optimum well design is no less important where a small capacity well is concerned than it is for one with a large capacity. Unfortunately, design and construction practices that produce efficient wells are often sacrificed in order to save on the cost of constructing a well, particularly in the case of small capacity wells. However, the increased cost of design and construction can be offset by decreased maintenance and operating costs over the long run, although it should be recognized that there is a limit to what can be achieved when compared to expenditure. Current design and construction technology is capable of producing wells with efficiencies of 80 to 90 percent. Pumping-plant or "wire-to-water" efficiency is currently at 65-70 percent.

Sanding

Irrespective of size or composition, any loose material entering a well is usually called "sand", and wells that regularly produce significant quantities of loose material are termed "sanders". The continued influx of sand to a well results in damage to pumps and leads eventually to decreased capacity, and thus a reduction in well efficiency. Further, enough sand may pass through the well to create cavities in the aquifer around the intake section of the well. As a result, such cavities can collapse and damage the well casing or screen. While most wells pump a minor amount of sand, excessive sanding is usually caused by poor well design or inadequate development.

Uncased ("Open-bottom") Wells. Casing serves to hold up the walls of the borehole and provide a path for the movement of the water. In formations with material that will not loosen and be carried away by the inflowing water, such as crystalline rock and other "hard rock" formations, the practice is to leave the intake sections uncased. (Theoretically in such instances, well efficiency would be 100 percent.) Unfortunately, in certain areas some drillers, believing the underlying material to be fully consolidated or attempting to save on costs, have drilled open-bottom wells that later produced sand. Furthermore, as pumps lowered following declining water levels, such wells developed sanding problems. This occurred in several areas in the Central Valley during the 1976-77 drought. In such instances, the wells should have been completely cased to prevent caving and the intake section screened to prevent the entrance of sand.

Inadequately Designed Intake Sections. Sanding is often the result of poor selection of screen size or perforation dimensions and/or, where used, filter material (the "gravel pack"). The well screen aperture (slot) openings or the perforation size, together with the length of screen or perforated section, should be selected to provide sufficient open area to allow the desired quantity of water to enter with minimal friction losses while keeping out 90 to 95 percent of the natural aquifer material or filter material.

Artificial filter materials perform a similar function. In addition to allowing the water to enter the well openings and preventing the entrance of fine-grained material, artificial filters are also used to increase the effective diameter of the well and increase the yield of certain wells by allowing numerous thin aquifers to produce water. On the other hand they need not be used unless there are conditions that make their use desirable or necessary.

Artificial filters are desirable when the aquifer has a "uniformity coefficient"1/ of less than 2.5 (some authorities recommend a value of less than 3), or in poorly consolidated rock, i.e., rock that tends to cave when pumping occurs.

Detailed information on the design of intake sections, including the selection of well screen aperture openings and artificial filter materials, will be found in most publications dealing with ground water and water wells, a number of which are listed in Appendix E.

Incomplete Development. Well construction causes compaction of unconsolidated material about the walls of the drilled hole and drilling fluid also invades these walls, forming a mud cake. In consolidated rocks, cuttings, fine particles and mud can be forced into joints and fractures. Thus, the borehole walls become clogged, reducing the potential yield and causing the drawdown to be increased. Proper well development breaks down the compacted walls (or opens fractures) and draws the material into the well where it can be removed. Obviously, the more thorough the development the better the well will perform. Adequacy of development is largely a matter of experience and judgment. The success of development can be measured by the amount of sand produced during interrupted pumping and the final specific capacity of the well.

Testing for Sand. The sand content should be tested after development and performance (pump) testing. Sand production should be measured by a centrifugal sand sampler2/ or other acceptable means. Following development (i.e., stabilization of the formation and/or gravel pack) and pump testing, the sand content should not exceed a concentration of 5 ppm (parts per million) by weight 15 minutes after the start of pumping.

Sand production exceeding this limit indicates that the well may not be completely developed or may not have been properly designed. In that event, redevelopment may be appropriate or as an alternative, a sand separator installed. In existing wells should this value be exceeded significantly, rehabilitation (redevelopment) or repair is probably needed. Again, as an alternative, a sand separator may need to be installed.

1/ The uniformity coefficient is a ratio that describes the variation in grain size of granular aquifer material. It is defined as the ratio of the particle size of a material at which 60 percent of the particles are finer and 40 percent are coarser (called D_{40}) to the "effective" grain size (i.e., the particle size of the material at which ten percent of the particles are finer and 90 percent are coarser) (D_{90}). The value of the uniformity coefficient for a material of one grain size is unity; for a heterogeneous sand it might be 30.

2/ Such a device is described in the Journal of the American Water Works Association, Volume 46, No. 2, February 1954.

Water Well Drillers' Reports

Detailed and comprehensive knowledge of the occurrence and quality of California's ground water resources is vital to protecting, conserving, and properly developing them. The data obtained during the construction of water wells are primary sources of geologic and hydrologic information. In 1949 the Legislature concluded that such information would be invaluable in the event of underground pollution, and would provide a fund of geologic information regarding the State's ground water resources. As a result, legislation was passed requiring the filing of a report with the Department. The report is called the Water Well Drillers' Report and its submittal is also a requirement of these standards (see Chapter II, Section 7 "Reports"). Additional information about the report is presented in "Guide to the Preparation of the Water Well Drillers' Report", Department of Water Resources, October 1977.

Comments and Public Hearings on Draft Edition

Where a publication 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 it in preliminary form and solicit comments from interested organizations and individuals and the general public. Since the standards for the construction of wells and the destruction of abandoned wells recommended herein are for application throughout the State, and because they are specified by many counties and cities (in ordinances or regulations), a draft edition was prepared and distributed for comment (April 14, 1981). In addition, four public hearings or meetings (of an informal nature) were held to obtain the views of persons interested in, or concerned with, the construction and use of water wells. These hearings were conducted in cooperation with the Department of Health Services represented by its Sanitary Engineering Section since this report contains provisions which pertain to the public health aspects of water well construction. The hearings were held during June 1981 at Berkeley, Fresno, Redding and Los Angeles. In response to a number of requests, the comment period was extended to September 1981.

Fifty-five persons representing 33 individuals and organizations attended the four hearings. Five formal (written) statements were presented and 16 persons commented verbally. In addition, written comments were received from 33 other organizations and individuals. Those submitting written comments are listed in Table 5. Copies of the written comments are available for inspection in the Department's file in Sacramento.

All comments were carefully reviewed and considered. As might be expected, opinions differed on the applicability of certain standards, guidelines, and procedures. There is, of course, some validity in each point-of-view, which forms the basis for reconsideration. Many comments were incorporated in this final draft. Others were not used for various reasons. Most of the comments dealt mainly with (1) the

TABLE 5
ORGANIZATIONS SUBMITTING WRITTEN COMMENTS
ON DRAFT OF BULLETIN 74-81

Organization	Representative	Date of Comments
Alameda Co. Water District	E. L. Lenahan	5/19/81
Associated Drilling Contractors	D. D. Mickel	8/7/81
Associated Drilling Contractors Tri Counties Branch	R. L. Strahan	6/9/81
Associated Drilling Contractors Tri Counties Branch	R. L. Strahan	9/14/81
Associated Drilling Contractors	D. B. Trunnell	5/20/81
Ballard & Foote Drilling	R. H. Foote Jr.	7/28/81
Buena Vista Water Storage Dist.	H. K. Russell	6/10/81
C & N Pump and Well Company	F. Clough	5/1/81
California Regional Water Quality Control Board - Central Valley Region	W. S. Johnson	8/27/81
California Regional Water Quality Control Board - Los Angeles Region	R. M. Hertel	9/10/81
California Regional Water Quality Control Board - San Francisco Bay Region	S. R. Ritchie	5/20/81
California Regional Water Quality Control Board - Santa Ana Region	R. R. Nicklen	6/8/81
California Water Service Company	G. W. Adrian	8/5/81
Clark Well & Equipment Co., Inc.	R. L. Clark	9/3/81
Coachella Valley Water District	L. O. Weeks	6/8/81
DeLucchi Well & Pump, Inc.	J. DeLucchi	6/25/81
Dougherty Pump & Drilling	C. L. Fasnacht	6/13/81
Dow Chemical U.S.A.	J. Jones	6/11/81
Fresno Co. Department of Health	C. Auernheimer	6/4/81
Robert Garcia Well & Pump Co.	R. E. Garcia	8/28/81
Harding-Lawson Associates	F. C. Kresse	8/28/81
Richard A. Hendry, Attorney-at-Law	R. A. Hendry	6/19/81
Michael F. Hoover	M. F. Hoover	5/20/81
Los Angeles Co. Department of Health Services	N. F. Hauret	6/10/81
Luhdorff & Scalmanini	E. E. Luhdorff Jr.	6/10/81
Monterey Co. Flood Control and Water Conservation District	R. R. Smith	6/9/81
Department of the Navy	W. N. Sorbo	6/17/81
Placer County Health Department	M. A. Winston	8/28/81
Santa Clara Valley Water Dist	J. L. Richardson	7/9/81
Santa Cruz Co. Environmental Health Services	L. R. Talley	5/28/81

TABLE 5
ORGANIZATIONS SUBMITTING WRITTEN COMMENTS
ON DRAFT OF BULLETIN 74-81 (Continued)

Organization	Representative	Date of Comments
Southern California Water Co.	D. F. Kostas	8/20/81
Stanislaus Co. Department of Environmental Resources	J. Aud	6/25/81
State Water Resources Control Board	C. Whitney	6/16/81
Joseph B. Summers, Civil Engineer, Inc.	J. B. Summers	6/5/81
Joseph B. Summers, Civil Engineer, Inc.	R. L. Reynolds	8/28/81
Tulare Lake Basin Water Storage District1	B. L. Graham	6/5/81
Ventura Co. Environmental Health Department	D. W. Koepp	6/8/81
Ventura Co. Public Works Agency	G. J. Nowak	8/14/81
Water Well Surveys	W. C. Wigley	6/16/81
Well Products West, Inc.	C. Willis	6/12/81
Well Products West, Inc.	C. Willis	8/4/81
Woodward-Clyde Consultants	J. A. Gilman	6/24/81

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standards in Chapter II (following) more specifically sections 1, 8, 9, 10, 11, 12, 13, 21 and 23; (2) the Design and Performance Guidelines section of this chapter; and (3) Appendixes B, C and D, which deal with methods and procedures.

HAPTER II. STANDARDS

The standards presented in this chapter are intended to apply to the construction (including major reconstruction) or destruction of water wells throughout the State of California. However, under certain circumstances, adequate protection of ground water quality may require more stringent standards than those presented here; under other circumstances, it may be necessary to substitute other measures which will provide protection equal to that provided by these standards. Such situations arise from practicalities in applying any standards or, in this case, from anomalies in ground water geology or hydrology. Since it is impractical to prepare standards for every conceivable situation, provision has been made for deviation from the standards as well as for additional ones. However, the Department believes that for most conditions encountered in the State, the standards presented in this report are satisfactory for the protection of ground water quality.

In the past, the Department expended considerable effort in defining areas where standards should be applied to prevent the mixing of waters of differing qualities in specific ground water areas in California. For example, ground waters of varying quality in the San Joaquin Valley are naturally separated by a confining bed commonly called the "Corcoran Clay". The standards presented in this chapter continue to support the findings and recommendations made ding the application of standards to the specific areas ously studied. (See Table 1, Chapter I.)

Par General

Section 1. Definitions

A. Well or Water Well. As defined in Sectio 13710 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 excavations during construction, or (2) stabilizing hillsides or earth embankments."

B. Community Water Supply Well. A water well used y water for domestic purposes in systems subject to hapter 7, Part 1, Division 5 of the California Health and afety Code. Included are wells supplying public water ystems classified by the Department of Health Services as

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nica te: are lef: ed in Appendix A

"Noncommunity water systems" and "State small water systems" (California Waterworks Standards, Title 22, California Administrative Code). Such wells are variously referred to as "Municipal Wells", "City Wells" or "Public Water Supply Wells".

C. Individual Domestic Well. A water well used to supply water for the domestic needs of an individual residence or systems of four or less service connections (or "hook-ups" as they are often called).

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 only 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, repelling the intrusion of seawater or disposing of waste water.1/

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), such 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 landslides).

I. Observation and Monitoring Wells. Wells constructed for the purpose of observing or monitoring ground water conditions.

1/ Included are wells used for the injection of reclaimed waste water. Injection wells are also used to dispose of unusable waste water into formations containing water of unusable quality (such as highly mineralized waters) or dry, nonproductive formations. These latter wells can penetrate usable ground water zones but are not permitted to open into usable water (Chapter 7, Division 7, California Water Code; Section 4458, California Health and Safety Code; and Chapter 1, Division 3, California Public Resources Code.) "Dry" wells, "drainage" wells, and sewer wells also fall into this category. Their existance and operation is also subject to the aforementioned provisions of the State law.

J. Test Wells. Wells constructed for the purpose of obtaining the information needed to design a well prior to its construction. Such wells are not to be confused with "test holes" or "exploration holes" which are temporary in nature (i.e., uncased excavations whose purpose is the immediate determination of existing geologic and hydrologic conditions). Test wells are cased and can be converted to observation or monitoring wells and under certain circumstances to production wells.

K. Inactive or Standby Well. A well not routinely operating but capable of being made operable with a minimum of effort.

L. Enforcing Agency. An agency designated by duly authorized local, regional or state government to administer laws or ordinances pertaining to well construction. For community water supply wells the enforcing agency is the State Department of Health Services or the local health department.

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.1/

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 or if compliance would result in construction of an unsatisfactory well, the enforcing agency may waive compliance and 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 exploration and test holes. However, the provisions of Section 7 "Reports" (following) and Part III, "Well Destruction", do apply to these holes.

Springs are excluded from these standards.2/

1/ An example would be an agricultural well converted to use as a community water supply well.

2/ Methods which can be used to protect water supplies furnished by springs and infiltration galleries are described in "Manual of Individual Water Supply Systems", U. S. Environmental Protection Agency, Office of Drinking Water (EPA-430/9-74-007).

Section 5. Special Standards.

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

B. Special standards are necessary for the construction of recharge or injection wells,1/ horizontal wells and other unusual types of wells. Design of these wells is subject to the approval of the enforcing agency.

Section Well Drille

The construction, alteration, or destructio wells shall be performed by contractors licensed in accordance with the provisions of the Contractors Lic La (Chapter 9, Division 3, of the Business and Professio ode unless exempted by that act.

Section 7. Reports.

Reports concerning the construction, a on, o destruction of water wells shall be filed with t fornia Department of Water Resources in accordance with t sions of Sections 13750 through 13755 (Division 7, Chapter 10, Article 3) of the California Water Cod

Part II. Well Construction

Section 8. Well Location with Respect to Contamina Pollutants.

A. All wells shall be located an adequate h i- zontal distance from potential sources of contaminatio an pollution.3/

1/ A program to protect underground drinking wate sources from endangerment by the subsurface emplacemen of fluids through well injection is required under the F deral Safe Drinking Water Act (Public Law 93-523) signed nto law December 16, 1974. On June 24, 1980, the U. Environmental Protection Agency issued rules and reg atio establishing technical criteria and standards over the construction of injection wells. Revisi August 27, 1981, and October 1, 1981. These gula are Part 146 of Title 40, Protection of Envir nent the Code of Federal Regulations (40CFR146).

2/ Information about the report is contained in Preparation of the Water Well Drillers Repo of Water Resources, October 1977.

3/ Such potential sources of contamination and p include: sewers, both sanitary and storm se fields (from septic tanks), sewage and indust ponds, barnyard and stable areas, feedlots, s disposal sites, tanks and pipelines (both abo gro buried) for storage and conveyance of petrole pro or chemicals, etc.

Most of the factors involved in determining safe distances in a particular area are usually not known. Based on past experience and general knowledge, the following horizontal distances are considered safe where dry upper unconsolidated formations, less permeable than sand, are encountered:1/2/

Sewer, watertight septic tank, or pit privy	50 feet (15 metres)
Subsurface sewage leaching field	100 feet (30 metres)
Cesspool or seepage pit	150 feet (45 metres)
Animal or fowl enclosure	100 feet (30 metres)

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 located up the ground water gradient (upstream) from the specified sources of contamination. By doing so this provides assurance that potential contamination would be moving naturally away from the area of production. However, in an unconfined aquifer consideration shall also be given to the possibility of reversal of gradient near the well due to pumping (see Figure 3), the pumping of nearby wells, or general decline of the water table.3/

C. The top of the casing shall terminate above grade or above any known conditions of flooding by drainage or runoff from the surrounding land. For community water supply wells this level is defined as above the

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1/ Because of the many variables involved in the 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.

2/ If the well is a radial collector well, these distances apply to the furthest extended points of the well.

3/ When water is pumped from a well a drawdown "cone of depression" is formed in the water surface surrounding the well and ground water in the area of the cone flows toward the well. Similar cones formed by nearby wells can influence the shape of the cone or enlarge the area being drawn upon resulting in a change in direction of flow.

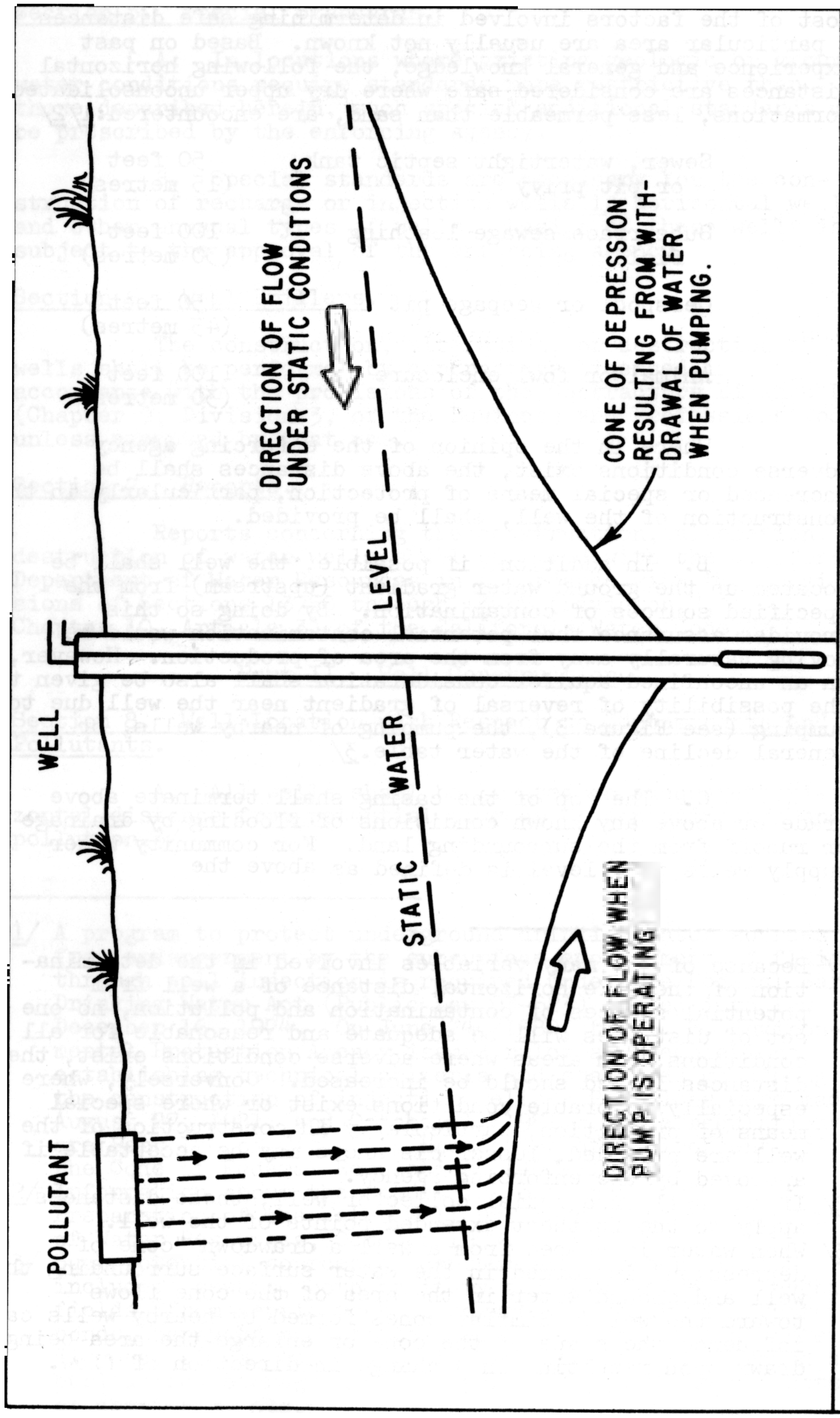

Figure 3. EFFECT OF REVERSAL OF GROUND WATER GRADIENT

"...floodplain of a 100 year flood..." or above "...any recorded high tide, ...", (Section 64417, "Siting Requirements", Title 22 of the California Administrative Code).1/

In addition, the area around the well shall slope away from the well and surface drainage shall be directed away from the well.

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

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 it against contamination or pollution by entrance of surface and/or shallow, subsurface waters.2/

A. Minimum depth of seal below ground surface for various uses of wells:

Types	Minimum Depth3/ of Seal (below ground surface)
Community Water Supply Wells	50 feet (15 metres)
Individual Domestic Wells	20 feet4/ (6.1 metres)
Industrial Wells	50 feet4/ (15 metres)
Agricultural Wells	20 feet4/5/ (6.1 metres)
Air-Conditioning Wells	20 feet4/ (6.1 metres)
Observation and Monitoring Wells	20 feet6/ (6.1 metres)

1/ If compliance with this requirement for community water supply wells is not possible, the enforcing agency should be contacted regarding alternative means for protection.

2/ Annular seals are also installed to provide protection for the casing against corrosion, to assure structural integrity of the casing, and to stabilize the upper formation.

3/ In those cases where it is not possible to meet or, when necessary, increase, the lateral distances from pollution sources described in Section 8 of these standards, an alternative (or special) means of protection for the well is to increase the depth of the seal.

4/ Exceptions are shallow wells where the water to be developed is at a depth less than 20 feet (6 metres). In this instance, the depth of seal may be reduced but in no case less than 10 feet (3 metres) and special precautions taken in locating the well with respect to sources of pollution.

5/ The annular space shall be sealed to a depth of 50 feet (15 metres) from the surface when the well is close to sources of pollution listed in Section 8.

6/ Because they are constructed to measure specific conditions, the annular space in such wells is usually sealed to make the intake section "depth-discrete". Depending on the circumstances, this depth may be very shallow.

In areas[1] where freezing is a potential problem, the top of the seal may be below ground surface but in no case more than 4 feet (1.2 metres) below ground surface.

Sealing Conditions.[2] Following are requirements to be observed in sealing the annular space:

1. Wells situated in unconsolidated, caving material. An oversized hole, at least 4 inches (100 millimetres) greater in diameter than the production casing, shall be drilled and a conductor casing installed to the depth of seal specified in Part A of this section. The space between the conductor casing and the production casing shall be filled with sealing material. The conductor may be withdrawn as the sealing material is placed (see Figure 4A).

2. Wells situated in unconsolidated material stratified with significant clay layers. If a clay formation is encountered within 5 feet (1.5 metres) of the bottom of the seal described in Part A of this section, the seal should be extended 5 feet (1.5 metres) into the clay formation (thus the depth of seal could be as much as another 10 feet or 3 metres). An oversized hole at least 4 inches (100 millimetres) greater in diameter than the production casing, shall be drilled and the annular space filled with sealing material (see Figure 4B).

If caving material is present, a conductor casing shall be installed and the annular space sealed as described in 1, above.

3. Wells situated in soft consolidated formations (extensive clays, sandstones, etc.). An oversized hole, at least 4 inches (100 millimetres) greater in diameter than the production casing, shall be drilled to the depth of seal specified in Part A of this section and the space between the production casing and the drilled hole shall be filled with sealing material (see Figure 4C).

If a conductor casing is to be installed (to establish a foundation for the construction of the remainder of the well) the oversized hole shall be at least 4 inches (100 millimetres) greater in diameter than the conductor

1/ Defined here as those areas in which the mean length of freeze-free period as described by the National Weather Service is less than 100 days, i.e., temperatures at or below 32°F (0°C) are likely to occur on any day during a period of 265 or more days each year. In general geographic terms, these areas are the northeastern part of the State (parts of Modoc, Lassen, and Siskiyou Counties), the north Lahontan area (essentially the eastern slopes of the Sierra Nevada and subsidiary valleys north of Mount Whitney and Mono Lake) and at Lake Arrowhead in the San Bernardino Mountains.

2/ Methods of sealing are described in Appendix B.

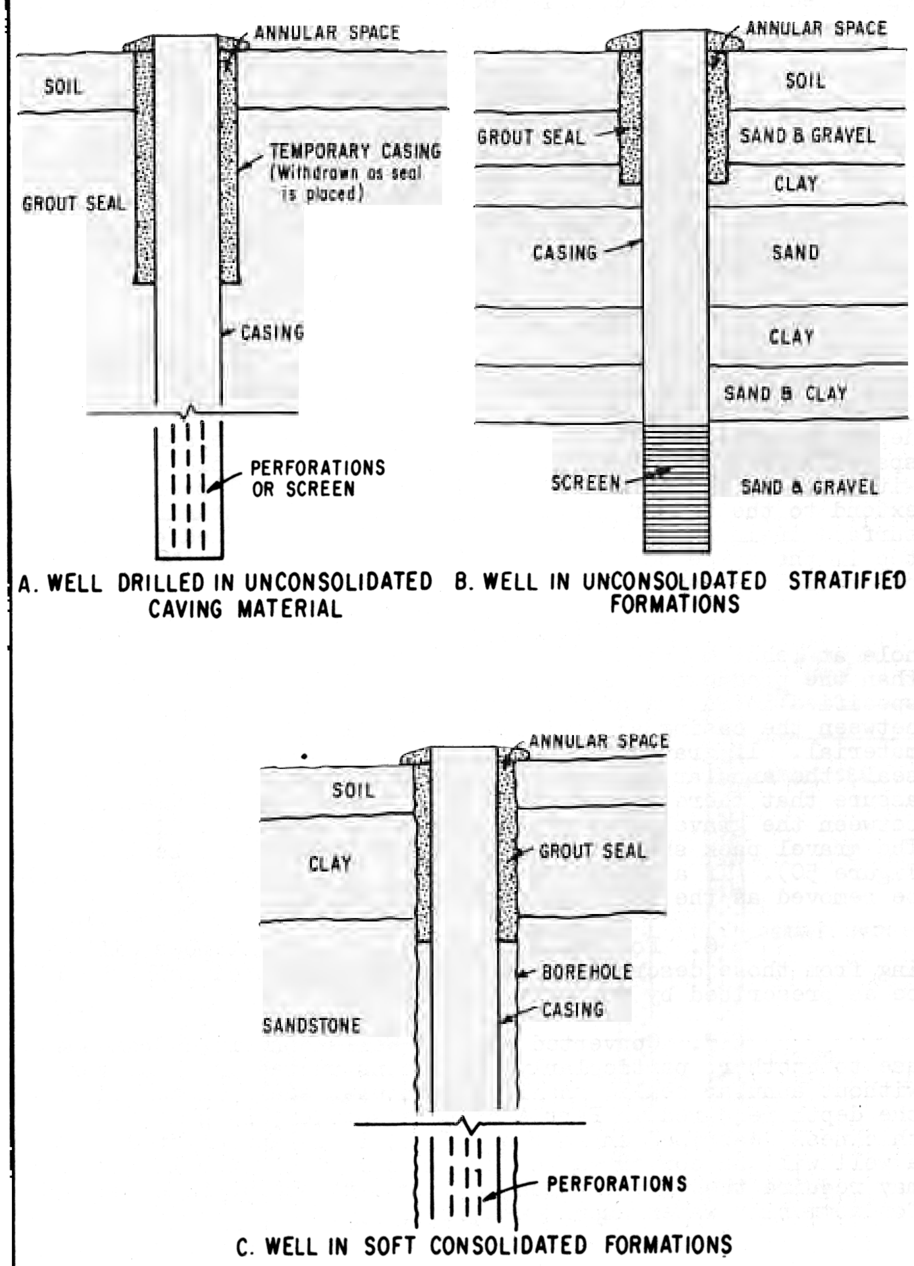

Figure 4. SEALING CONDITIONS FOR UPPER ANNULAR SPACE-UNCONSOLIDATED AND SOFT, CONSOLIDATED FORMATIONS

casing and the annular space between the conductor casing and the drilled hole filled with sealing material to the depth specified in Part A of this section.

4. Wells situated in "hard" consolidated formations (crystaline or metamorphic rock). An oversized hole shall be drilled to the depth specified in Part A of this section and the annular space filled with sealing material. If there is significant overburden, a conductor casing may be installed to retain it. If the material is heavily fractured, the seal should extend into solid material. If the well is to be open-bottomed (lower section uncased), the casing shall be seated in the sealing material (see Figure 5A).

5. Gravel packed wells.

a. With conductor casing. An oversized hole, at least 4 inches (100 millimetres) greater than the diameter of the conductor casing, shall be drilled to the depth specified in Part A of this section and the annular space between the conductor casing and drilled hole filled with sealing material. (In this case the gravel pack may extend to the top of the well but to prevent contamination by surface drainage, a welded cover shall be installed over the top in the space between the conductor casing and the production casing, see Figure 5B).

b. Without conductor casing. An oversized hole at least 4 inches (100 millimetres) greater in diameter than the production casing, shall be drilled to the depth specified in Part A of this section and the annular space between the casing and drilled hole filled with sealing material. If gravel fill pipes are installed through the seal, the annular seal shall be of sufficient thickness to assure that there is a minimum of 2 inches (50 millimetres) between the gravel fill pipe and the wall of the drilled hole. The gravel pack shall terminate at the base of the seal (see Figure 5C). If a temporary conductor casing is used, it shall be removed as the sealing material is placed.

6. For wells situated in circumstances differing from those described above, the sealing conditions shall be as prescribed by the enforcing agency.

7. Converted wells. Wells converted from one use to another, particularly those constructed in prior years without annular seals, shall have annular seals installed to the depth required in Part A of this section and at the thickness described in Part E. Where it is anticipated that a well will be converted to another use, the enforcing agency may require the installation of a seal to the depth specified for community water supply wells.1/

1/ This statement presumes that land use planning has taken place and that zoning requirements are in effect.

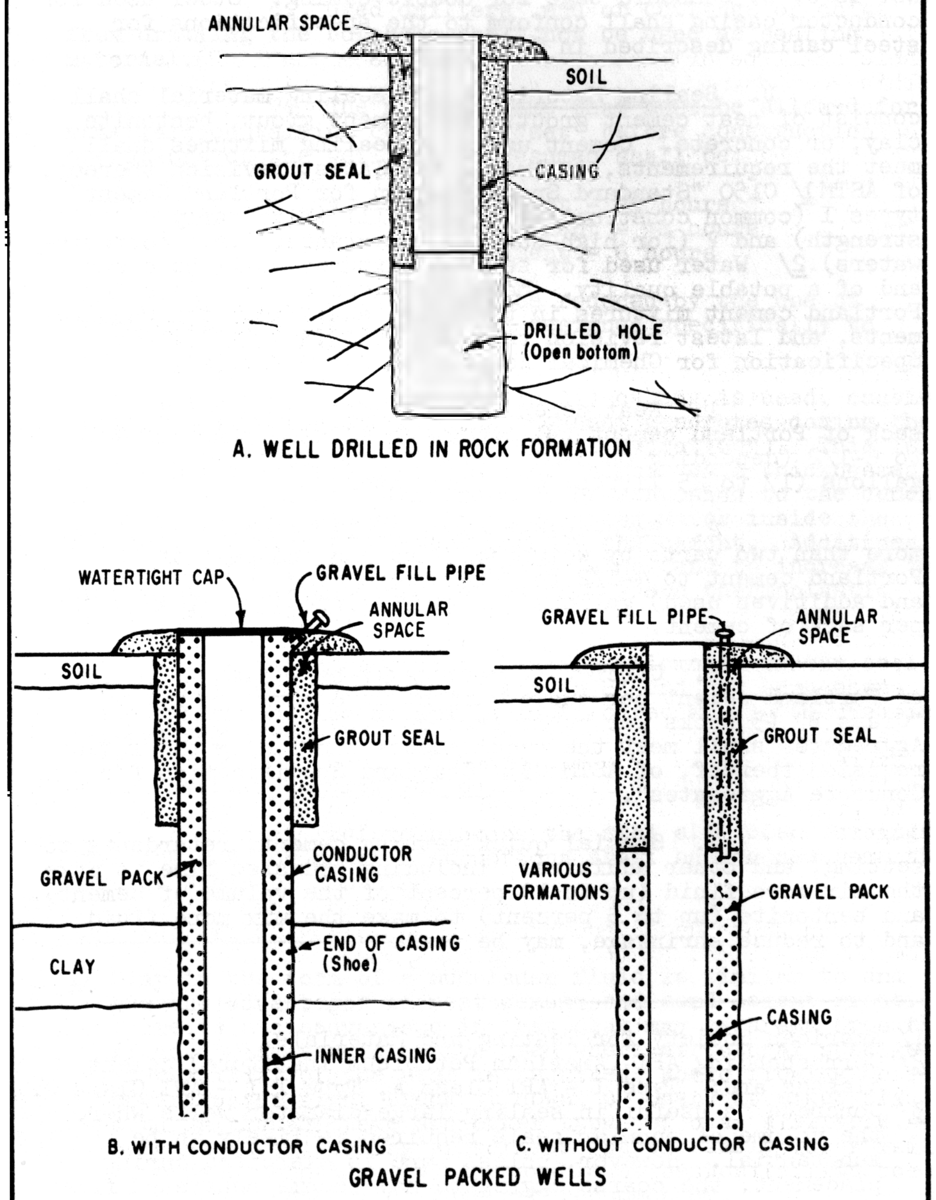

Figure 5. SEALING CONDITIONS FOR UPPER ANNULAR SPACE-HARD ROCK FORMATIONS AND GRAVEL PACKED WELLS

C. Conductor Casing. For community water supply wells, the minimum thickness of steel conductor casing shall be 1/4 inch (6 millimetres) 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 grout, sand-cement grout, bentonite clay, or concrete. Cement used for sealing mixtures shall meet the requirements, including the latest revision thereof, of ASTM1/ C150 "Standard Specification for Portland Cement" types I (common construction cement) III (high early strength) and V (for high sulfate resistance, i.e., corrosive waters).2/ Water used for sealing mixtures shall be clean and of a potable quality. Materials used as additives for Portland cement mixtures in the field shall meet the requirements, and latest revision thereof, of ASTM C494 "Standard Specification for Chemical Admixtures for Concrete".

1. Neat cement grout shall be composed of one sack of Portland cement (94 pounds or 43 kilograms) to 4-1/2 to 6-1/2 (depending on cement type and additives used) gallons (17 to 25 litres) of clean water.

2. Sand-cement grout shall be composed of not more than two parts by weight of sand and one part of Portland cement to 4-1/2 to 6-1/2 (depending on cement type and additives used) gallons (17 to 25 litres) of clean water per sack of cement.

3. Concrete3/ used shall be "Class A" (6 sacks of Portland cement per cubic yard or 0.76 cubic metre) or "Class B" (5 sacks per cubic yard or 0.76 cubic metre).4/ Aggregates shall meet the requirements, including the latest revision thereof, of ASTM C33 "Standard Specification for Concrete Aggregates".

4. Special 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.

1/ American Society for Testing and Materials.
2/ Corresponding API (American Petroleum Institute) cement classes are: Type I - API Class A, Type III - API Class C.
3/ Concrete is useful in sealing large-diameter wells where the volume of annular seals required is likely to be substantial. However, unless care is exercised during placement, the coarse aggregate may become separated from the cement.
4/ A popular concrete mix among drillers consists of 8 sacks of Portland cement per cubic yard (0.76 cubic metre) and uniform aggregate of 3/8 inch (9.5 millimetres) diameter.

5. Bentonite clay1/ mixtures shall be composed of bentonite clay and clean water thoroughly mixed before placement so that there are no balls, clods, etc.

6. Used drillers' mud or cuttings or chips from drilling the borehole shall not be used as sealing material.

7. The minimum time that must be allowed for materials containing cement to "set" before construction operations on the well may be resumed shall be:

a. Type I cement - 72 hours
b. Type III cement - 48 hours
c. Type V cement - 6 hours

When necessary these times may be reduced by the use of "accelerators", i.e., additives designed specifically to shorten setting time.

8. Where thermoplastic casing is used, caution should be exercised to control the heat generated during the curing of the cement (called "heat of hydration"). This is of special concern where casing of thinner wall thicknesses are to be installed. The addition of bentonite to the cement mixture (up to 8 percent) or circulating water inside the casing will lower the temperature of the cement. Additives which accelerate the curing process also tend to increase the heat generated and should not be used where thermoplastic casing is installed.

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

F. Placement of Seal.

1. Before placing the seal all loose cuttings, drilling mud, or other obstructions shall be removed from the annular space by flushing.

1/ Clay in the form of a mud-laden fluid is similar to and has the advantages of neat cement and sand-cement grout. There is a disadvantage in that clay may separate from the fluid. Clay should not be used where structural strength or stability of the seal is required, where flowing or moving water might break it down, or where it might dry out. Although there are other types of clay available, none have the sealing properties (particularly the ability to expand dramatically) comparable to bentonite. Therefore, only bentonite clays are recommended.
2/ In other words, the borehole shall be nominally 4 inches (100 millimetres) larger in diameter than the nominal casing diameter (thus creating a 2-inch, or-50 millimetre annular space).

2. Before sealing commences a packer or similar retaining device or a small quantity of sealant may be placed and permitted to set at the bottom of the interval to be sealed to form a foundation for the seal.

3. The sealing material shall be applied, when possible, in one continuous operation from the bottom of the interval to be sealed to the top. Where the seal is to be very deep (i.e., greater than 100 feet or 30 metres) a short segment at least 10 feet (3 metres) in length may be installed first, allowed to "set" or partially "set" and then the remainder of the seal placed in one continuous operation.

4. Gravity installation of sealant without the aid of a tremie or grout pipe shall not be used unless the interval to be sealed is dry and in no case where the interval is over 30 feet (9 metres) in depth.

Section 10. Surface Construction Features.

A. Openings. Openings into the top of the well which are designed to provide access to the well, i.e., for measuring, chlorinating, adding gravel, etc., shall be protected against entrance of surface waters or foreign matter by installation of watertight caps or plugs. Access openings designed to permit the entrance or egress of air or gas (air or casing vents) shall terminate above the ground and above known flood levels and shall be protected against the entrance of foreign material by installation of down-turned and screened "U" bends (see Figures 6 and 7).

All other openings (holes, crevices, cracks, etc.) shall be sealed.

A "sounding tube",1/ taphole with plug, or similar access (see Figure 6) for the introduction of water level measuring devices shall be affixed to the casing of all wells. For wells fitted with a "well cap" the cap shall have a removable plug for this purpose.

1. Where the pump is installed directly over the casing, a watertight seal (gasket) shall be placed between the pump head and the pump base (slab), or a watertight seal (gasket) shall be placed between the pump base and the rim of the casing, or a "well cap" shall be installed to close the annular opening between the casing and the pump column pipe (see Figures 6 and 7).

1/ A "sounding tube" or similar access is necessary so that the water level in the well can be periodically determined. Knowledge of the water level, both static and pumping levels, is vital to the maintenance of the well and pump and for determining the efficiency of pump. Such information will lead to few and less costly repairs and reduce operating costs.

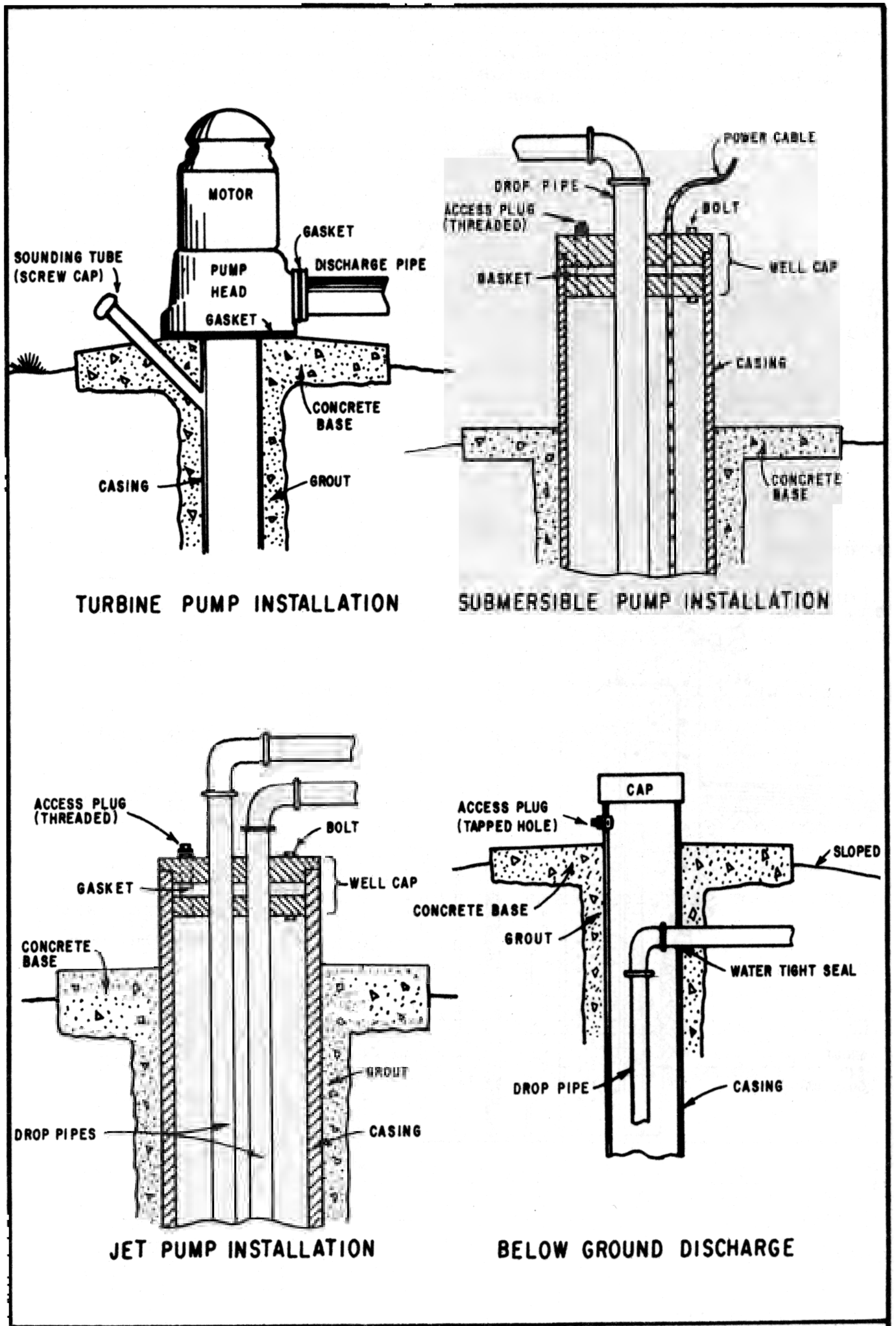

Figure 6. TYPICAL SURFACE CONSTRUCTION FEATURES

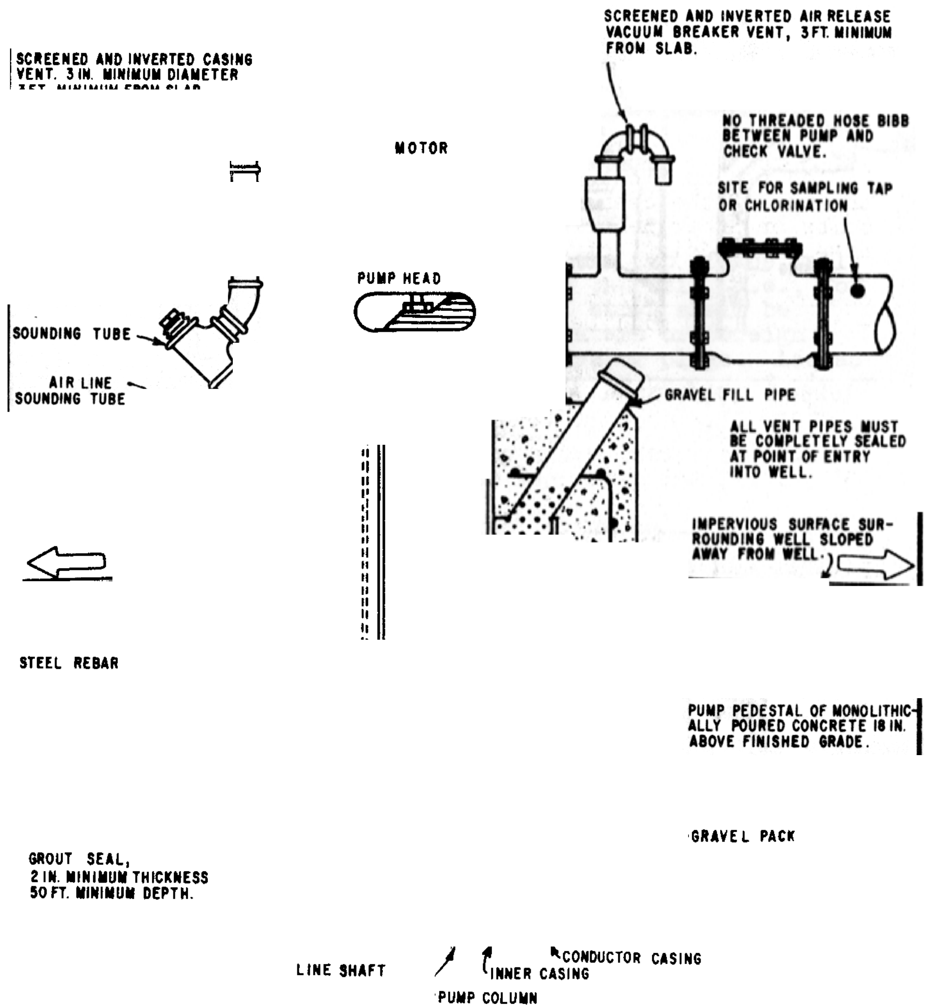

Figure 7. SURFACE CONSTRUCTION FEATURES COMMUNITY WATER SUPPLY WELL

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

4. A watertight seal or gasket shall be placed between the pump discharge head and the discharge line; or, in the event of a below-ground discharge, between the discharge pipe and discharge line (see Figures 6 and 7).

5. If a concrete base or slab (sometimes called a pump block or pump pedestal) is constructed around the top of the casing, it shall be free from cracks, honeycombs or other defects likely to detract from its watertightness. The joint between the base and the annular seal must also be watertight. The base shall slope away from the well casing. The minimum thickness of the concrete base shall be 4 inches (100 millimetres).1/

6. Where the well is to be gravel packed and the pack extends to the surface, a watertight cover shall be installed between the conductor casing and the inner casing (see also Section 9, Part B, Item 5 and Figure 5).

B. Well Pits. Because of their susceptability to contamination and pollution, the use of well pits should be avoided whenever possible. A substitute device called a pitless adapter2/ or pitless adapter unit (a variation) may be used in place of a well pit.

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

1/ This value is for small (under 10 inches or 250 millimetres in diameter) individual domestic well installations. The shape and dimensions of pump bases varies with the size, weight, and type of pumping equipment to be installed and the bearing capacity of the soil on which it is situated. A variety of designs have been used. For large diameter turbine pump installations the Vertical Turbine Pump Association has developed a standard design for a square, concrete pump base that is based on weight, including full pump column and soil bearing capacity. (See Bibliography, Appendix E.)

2/ Pitless adaptors and units were developed for use in areas where prolonged freezing occurs and below ground (below frost line) discharges are common. Both the National Sanitation Foundation and Water Systems Council have developed standards for their manufacture and installation. (See Bibliography, Appendix E.)

D. Pump Blowoff. When there is a blowoff or drain line from the pump discharge, it shall be located above any known flood levels and protected against the possibility of backsiphonage or backpressure. The blowoff or drain line shall not be connected to any sewer or storm drain except when connected through an air gap.

E. Air Vents. In community water supply wells to minimize the possibility of contamination caused by the creation of a partial vacuum during pumping, a casing vent shall be installed (Figure 7). In addition, to release air trapped in the pump column when the pump is not running, air release vents shall be installed (Figure 7). Air vents are also recommended for other types of wells except those having jet pump installations requiring positive pressure (which cannot have a vent).

F. Backflow Prevention.1/ All pump discharge pipes not discharging to the atmosphere shall be equipped with a check valve or similar device to prevent backflow and/or backsiphonage into the well when the pump shuts down. The check valve shall be installed between the pump head and the connection to the distribution system or standpipe.

Section 11. Disinfection and Other Sanitary Requirements.

A. Disinfection.2/ All wells producing water for domestic use (i.e., drinking or food processing) 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 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.

During placement of the gravel in the annular space disinfectants (usually calcium hypochlorite in tablet or granular form) shall be added to the gravel at a uniform rate (two tablets per cubic foot or one pound of the granular form per cubic yard).

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.

1/ The potential for the accidental contamination of wells through backflow or backsiphonage is high, particularly where there is the possibility of interconnection with other systems or in systems where agricultural chemicals (fertilizers, pesticides, etc.) are being injected.

2/ A procedure for disinfecting a well is described in Appendix C.

Section 12. Casing.

A. Casing Material.1/ 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.

1. Well casing shall be strong and tough enough to resist the forces imposed on it 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. The thickness of steel used for well casing shall be selected in accordance with good design practices applied with due consideration to conditions at the site of the well.2/ 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.

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

2/ 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 practices preclude 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 ensure that the casing selected will resist all probable forces imposed upon it. Consequently, experience and sound judgment, coupled with these factors or 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 publications on the design of water wells. The suggested thicknesses contained in such publications are not to be considered a part of these standards.

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 Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless".

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

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

(6) ASTM A135, "Standard Specification for Electric-Resistance-Welded Steel Pipe".

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

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

(9) AWWA C200, "AWWA Standard for Steel Water Pipe 6 Inches and Larger".

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, "Standard Specification for Structural Steel".

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

3) ASTM A283, "Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality".

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

(5) ASTM A570, "Standard Specification for Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality".

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 markings 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. Stainless steel casing shall meet the provisions of ASTM A409, "Standard Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High Temperature Service".

3. Plastic is also used as casing for water wells in many locations under a variety of circumstances.1/ Because large-diameter (10 inches or 250 millimetres and larger) plastic casing has not been used extensively and especially at depths exceeding 300 feet (90 metres), special care must be exercised in the design and construction of wells that will employ these sizes. Particular attention should be given to the effect on thermoplastic casing of heat generated during cementing operations (see also Part B, "Installation of Casing" of this section, item 8, Part D, "Sealing Material" of Section 9, and discussion of plastic casing in Chapter I).

There are two groups of plastic materials available: thermoplastics and thermosets. Thermoplastics soften with the application of heat and reharden when cooled. Thus they can be repeatedly reformed. Thermosets cannot be reformed. During manufacture their molecules are permanently "set" by heat, chemical action or a combination of both. Thermoplastics used for plastic casing are ABS (acrylonitrile butadiene styrene), PVC (polyvinyl chloride) and SR (styrene rubber). The thermosetting plastic used for casing is fiberglass.

1/ Information about the selection and installation of thermoplastic casing will be found in "Manual on the Selection and Installation of Thermoplastic Water Well Casing", a joint publication of the National Water Well Association and the Plastic Pipe Institute.

a. Thermoplastics. This material shall meet the requirements of ASTM F480, "Standard Specification for Thermoplastic Water Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR)" including the latest revision thereof.1/ SDR is the ratio of pipe diameter to wall thickness.

b. Thermosets. This material shall meet the requirements of the following specifications including the latest revisions thereof:

(1) ASTM D2996, "Standard Specification for Filament Wound Reinforced Thermosetting Resin Pipe".

(2) ASTM D2997, "Standard Specification for Centrifugally Cast Reinforced Thermosetting Resin Pipe".

(3) ASTM D3517, "Standard Specification for Reinforced Plastic Mortar Pressure Pipe".

(4) AWWA C950, "AWWA Standard for Glass-Fiber-Reinforced Thermosetting-Resin Pressure Pipe".

c. All plastic casing used for community water supply wells and individual wells shall meet the provisions of National Sanitation Foundation Standard No. 14 for Plastic Piping System Components and Related Materials.2/

d. Plastic casing should not be stored in direct sunlight or subjected to freezing temperatures for extensive periods of time. Further, it should be stored so as to prevent sagging or bending.

4. Concrete pipe used for casing should conform to the following specifications, including the latest revision thereof:

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

1/ Certain sizes of ABS and PVC plastic pipe products made in Schedule 40 and 80 (and others) wall thicknesses correspond to or overlap some of the sizes described in ASTM F480. However, this does not mean that they are equivalent products. They are classified in ASTM F480 as well casing specials referencing ASTM Specifications D1527 (for ABS pipe) and ASTM D1785 and D2241 (for PVC pipe).

2/ NSF Standard No. 14 includes the requirements of ASTM F480 described in paragraph a, preceding.

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

(c) AWWA C300, "AWWA Standard for Reinforced Concrete Pressure Pipe Steel Cylinder Type, for Water and Other Liquids".

(d) AWWA C301, "AWWA Standard for Prestressed Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids".

5. Other materials,1/ except as listed in No. 6 below, may be used as casing for water wells, subject to the approval of the enforcing agency.

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

B. Installation of Casing. All casing shall be placed with sufficient care to avoid damage to casing sections and joints. All joints in the casing above the 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". Casing shall be equipped with centering guides to ensure even thickness of annular seal and/or gravel pack.

1. Metallic casing. Steel casing may be joined by either welding or by threading and coupling. Welding shall be accomplished in accordance with standards of American Welding Society or the most recent revision of the American Society of Mechanical Engineers Boiler Construction Code. 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.

2. Plastic (non-metallic) casing.2/ Depending on the type of material and its fabrication, plastic casing may be joined by solvent welding or mechanically joined (threaded or otherwise coupled). The solvent cement used for solvent welding shall meet the specifications for the type of plastic used and shall be applied in accordance with the manufacturer's instructions, particularly those pertaining to setting time required for the joint to develop handling strength. An adapter shall be used to join plastic casing to metallic casing or screen.

1/ Such as wrought iron, asbestos cement pipe, and synthetic woods, all of which have been successfully employed as casing in California or elsewhere. Their present use is limited to special cases. Specifications for most of these materials are published by either ASTM or AWWA.

2/ Information about the installation of thermoplastic casing will be found in "Manual on the Selection and Installation of Thermoplastic Water Well Casing", a joint publication of the National Water Well Association and the Plastic Pipe Institute.

Plastic casing or screen shall not be driven or otherwise subjected to impact forces during installation. The effects of heat generated by curing cement on plastic casing are discussed in Section 9, Part B, paragraph 8.

Section 13. Sealing-off Strata.

In areas where a well penetrates more than one aquifer, and one or more of the aquifers contains water 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 poor-quality water shall be sealed off to prevent entrance of the water into the well or its migration to other aquifer(s).

A. Strata producing the undesirable quality water shall be sealed off by placing impervious material opposite the strata and opposite the confining formation(s). (See Figure 8.) The seal shall extend above and below the strata no less than 10 feet (3 metres) even should the confining formation be less than 10 feet (3 metres) in thickness. In the case of "bottom" waters, the seal shall extend 10 feet (3 metres) in the upward direction. The sealing material shall fill the annular space between the casing and the wall of the drilled hole in the interval to be sealed, and the surrounding void spaces which might absorb the sealing material. The sealing material shall be placed from the bottom to the top of the interval to be sealed.

In areas where deep subsidence may occur (as, for example, portions of the San Joaquin Valley) provision shall be made for maintaining the integrity of the annular seal in the event of subsidence. Such preventive measures may include the installation of a "sleeve" or "slip joint" in the casing, which will allow vertical movement in the casing without its collapse.

B. Sealing material shall consist of neat cement, cement grout, or bentonite clay (see Section 9, Part D for description of the various materials).

C. Sealing shall be accomplished by a method approved by the enforcing agency.1/

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.

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

1/ Suggested methods for sealing-off strata are presented in Appendix B.

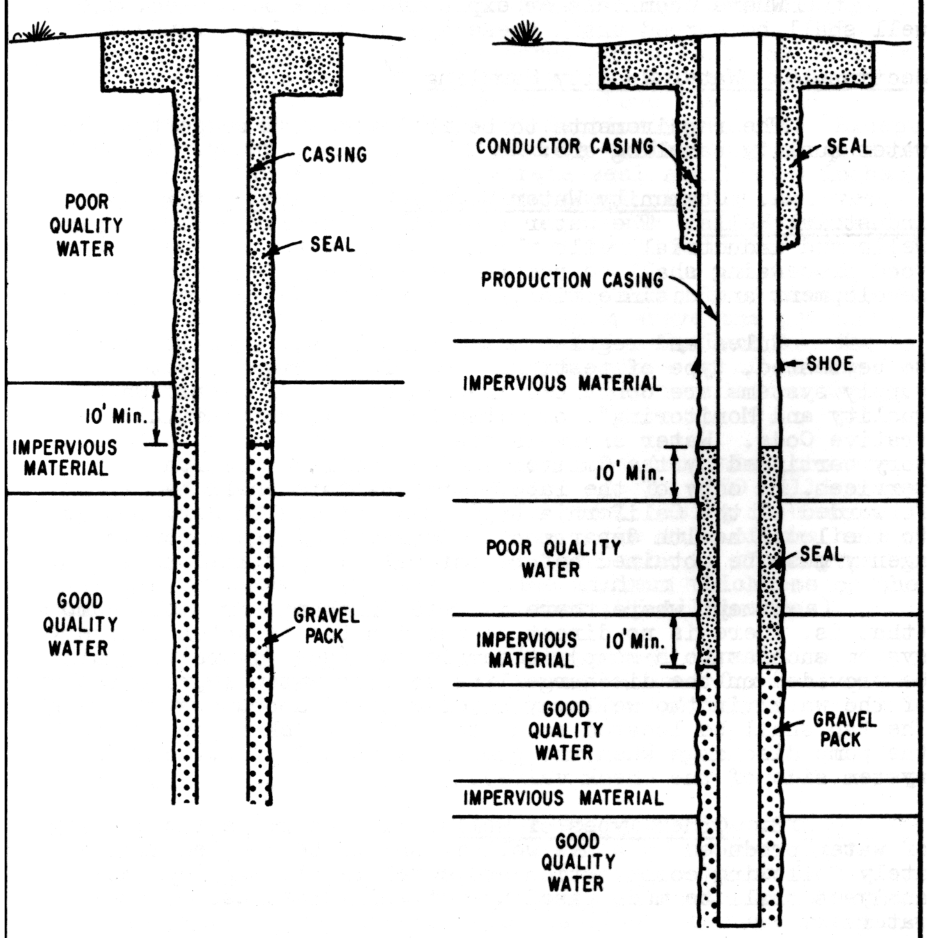

Figure 8. SEALING-OFF STRATA

plunger, (c) surging with compressed air, (d) backwashing or surging by alternately starting and stopping the pump, (e) jetting with water, (f) introduction of chemicals designed for this purpose, and (g) a combination of the above.

The use of explosives for development should be done only by persons trained to handle them. Further, they should be used with special care where two or more distinct aquifers separated by a natural barrier have been penetrated.

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

Section 15. Water Quality Sampling.[1/]

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 made.

Rules and regulations governing the constituents to be tested, type of testing, etc., for community water supply systems are contained in Chapter 15, "Domestic Water Quality and Monitoring", of Title 22, California Administrative Code. Water analysis shall be performed by a laboratory certified by the California Department of Health Services. A copy of the laboratory analysis shall be forwarded to the California Department of Health Services or to the local health department. Approval of the enforcing agency must be obtained before the well is put into use.

Except where there is free discharge from the pump (that is, there is no direct connection to the water delivery system such as to a sump), a sample tap (see Figure 7) shall be provided on the discharge line so that water representative of the water in the well may be drawn for laboratory analysis. The tap shall be located so as to prevent back siphonage to the pump discharge when the pump is shut off (e.g., on the system side of the check valve).

B. Other Types of Wells. To determine the quality of water produced by a new well it should be sampled immediately following construction and development. Appropriate analyses shall be made based upon the intended uses of the water.

1/ The collection of water quality samples is described in Appendix D.

Section 16. Special Provisions for Large Diameter Shallow Wells.

A. Use as Community Water Supply Wells. Because shallow ground waters are often of poor quality and because they are easily contaminated, the use of bored or dug wells, or wells less than 50 feet (15 metres) 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 (76 metres) 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 (150 millimetres) above the ground surface to the depths specified in Section 9, Part A. Except where corrugated steel pipe is used as casing, the minimum thickness of the surrounding concrete seal shall be 3 inches (75 millimetres). Where corrugated steel pipe is employed, the joints are not watertight and a thicker annular seal (no less than 6 inches or 150 millimetres) shall be installed.

C. Dug Wells. All dug wells shall be "curbed" with a watertight curbing extending from above the ground 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 6 inches (150 millimetres) 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 3 inches (75 millimetres).

D. Casing Material. Either steel (including corrugated steel pipe) or concrete may be used for casing bored or dug wells. Corrugated aluminum pipe is not recommended for use as casing.[1/]

1/ Aluminum placed in an aggressive soil is subject to electrolytic corrosion. When the soil pH is very high (over 8.0) or very low (under 6.0) this could present problems and, therefore, the soil pH ought to be checked. In addition, galvanic corrosion is likely to take place unless the pump is also made of aluminum. Accordingly, the use of most of the aluminum alloys currently available is not recommended.

1. Steel used in the manufacture of casing for bored and dug wells should conform to the specifications for casing material described in Section 12. Minimum thickness of steel casing for bored and dug wells shall be:

Diameter		U. S. Standard Gage
Inches	Millimetres	or Plate Thickness
18	450	8 gage (4.18 millimetres)
24	600	1/4 inch (6.35 millimetres)
30	750	1/4 inch (6.35 millimetres)
36	900	1/4 inch (6.35 millimetres)
42	1050	1/4 inch (6.35 millimetres)
48	1150	1/4 inch (6.35 millimetres)

Corrugated steel pipe used as casing shall meet the specifications (including the latest revision) of ASTM1/ A444, "Standard Specification for Steel Sheet, Zinc Coated (Galvanized) by the HOT-DIP Process for Culverts and Underdrains". The minimum thickness of sheet used shall be 0.109 inches (2.8 millimetres).

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 during, as well as after, construction. 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 place without "bridging" should be used. Poured-in-place concrete shall be "Class A" (6 sacks of Portland cement per cubic yard or 0.76 cubic metre) or "Class B" (5 sacks per cubic yard or 0.76 cubic metre).

Precast concrete pipe is usually composed of concrete rings from 1 to 6 feet (0.3 to 1.8 metres) in diameter and approximately 3 to 8 feet (0.9 to 2.4 metres) long. To serve satisfactorily as casing, these rings should be free of blemishes that would impair their strength or serviceability. Concrete pipe shall conform to the specifications listed in Section 12, Part A, item 4.

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

1/ American Society for Testing and Materials.

Section 17. Special Provisions for Driven Wells ("Well Points").

A. If the well is to be used as an individual domestic well, an oversize hole with a diameter at least 3 inches (75 millimetres) greater than the diameter of the pipe shall be constructed to a depth of 6 feet (1.8 meters) and the annular space around the pipe shall be filled with neat cement, cement grout, or bentonite mud.

B. The minimum wall thickness of steel drive pipe shall be not less than 0.140 inches (3.5 millimetres).

C. Well points made of thermoplastic materials should not be driven but jetted or washed into place.

Section 18. Rehabilitation, Repair and Deepening of Wells.

A. Rehabilitation is the treatment of a well by chemical or mechanical means (or both) to recover lost production caused by incrustation or clogging of screens or the formation immediately adjacent to the well. The following methods used for rehabilitating a well when done with care are acceptable: (1) introduction of chemicals designed for this purpose, (2) surging by use of compressed air, (3) backwashing or surging by alternately starting or stopping the pump, (4) jetting with water, (5) sonic cleaning, (6) vibratory explosives, and (7) combinations of these. Methods which produce an explosion (in addition to the use of vibratory explosives mentioned above) are also acceptable provided, however, they are used with great care, particularly where aquifers are separated by distinct barriers to the movement of ground water.

In those cases where chemicals or explosives have been used, the well shall be pumped until all traces of them have been removed.

B. In the repair of wells, material used for casing shall meet the requirements of Section 12 "Casing" of these provisions. In addition, the requirements of Section 11, Part A "Disinfection" and, when applicable, Section 14 "Sealing-off Strata" shall be followed.

C. Where wells are to be deepened, the requirements of Sections 11, 12, 13, 14, and 15 of these standards shall be followed.

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. The cover shall be held in place or "weighted-down" in such a manner that it cannot be removed except with the aid of equipment or through the use of tools.

During prolonged interruptions (i.e., 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.

A well that is no longer useful[1/] (including exploration and test holes) must be destroyed in order to:

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

2. Eliminate the potential physical hazard.

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 demonstrates his intention to use the well again for supplying water or other associated purpose[2/] (such as an observation well or injection well). The well shall then be considered "inactive". 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 allow the impairment of quality of water in the well or in the water-bearing formations penetrated.

2. The well is covered such that the cover is watertight and cannot be removed except with the aid of equipment or the use of tools.

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.

1/ Very often wells are prematurely abandoned and destroyed. However, proper maintenance will ensure that they will continue to produce for many years. The maintenance program should include regular measurement of the water level (depth to water from ground surface), determination of water quality, pump tests (for determination of pump and well efficiency) and cleaning.

2/ 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 and Section 13540 of the Water Code).

If the pump has been removed for repair or replacement, the well shall not be considered "abandoned". 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 or test wells used in the investigation or management of ground water basins by governmental agencies or engineering or research organizations are not considered "abandoned" so long as they are maintained for this purpose. However, such wells shall be covered with 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 and exploration or test holes shall be destroyed. The objective of destruction 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.)

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. Preliminary Work. Before the well is destroyed, it 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. This may include the use of downhole television and photography for visual inspection of the well.

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

2. Where necessary, to ensure that sealing material fills not only the well casing but also any annular space or nearby voids within the zone(s) to be sealed, the casing should be perforated or otherwise punctured.

3. In some wells, it may be necessary or desirable to remove a part of the casing. However, in many instances this can be done only as the well is filled. For dug wells, as much of the lining as possible (or safe) should be removed prior to filling.

B. 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 (Figure 9A). If the ground water supplies are within 50 feet (15 metres) of the surface, the upper 20 feet (6 metres) shall be sealed with impervious material and the remainder of the well shall be filled with clay, sand, or other suitable inorganic material (see item D, this section).

2. Well penetrating several aquifers or formations. In all cases the upper 20 feet (6 metres) of the well shall be sealed with impervious material.

In areas where the interchange of water between aquifers will result in a significant1/ 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 and other formations where impervious sealing material is not required. To prevent the vertical movement of water from the producing formation, impervious material must be placed opposite confining formations above and below the producing formations for a distance of 10 feet (3 metres) or more. 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 or 3 metres) in both directions, or in the case of "bottom" waters, in the upward direction. (See Figure 9B.)

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.

1/ 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 U. S. 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. Examples 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. An excellent example of a "bottom" water is the saline connate water underlying the Central Valley at varying depths.

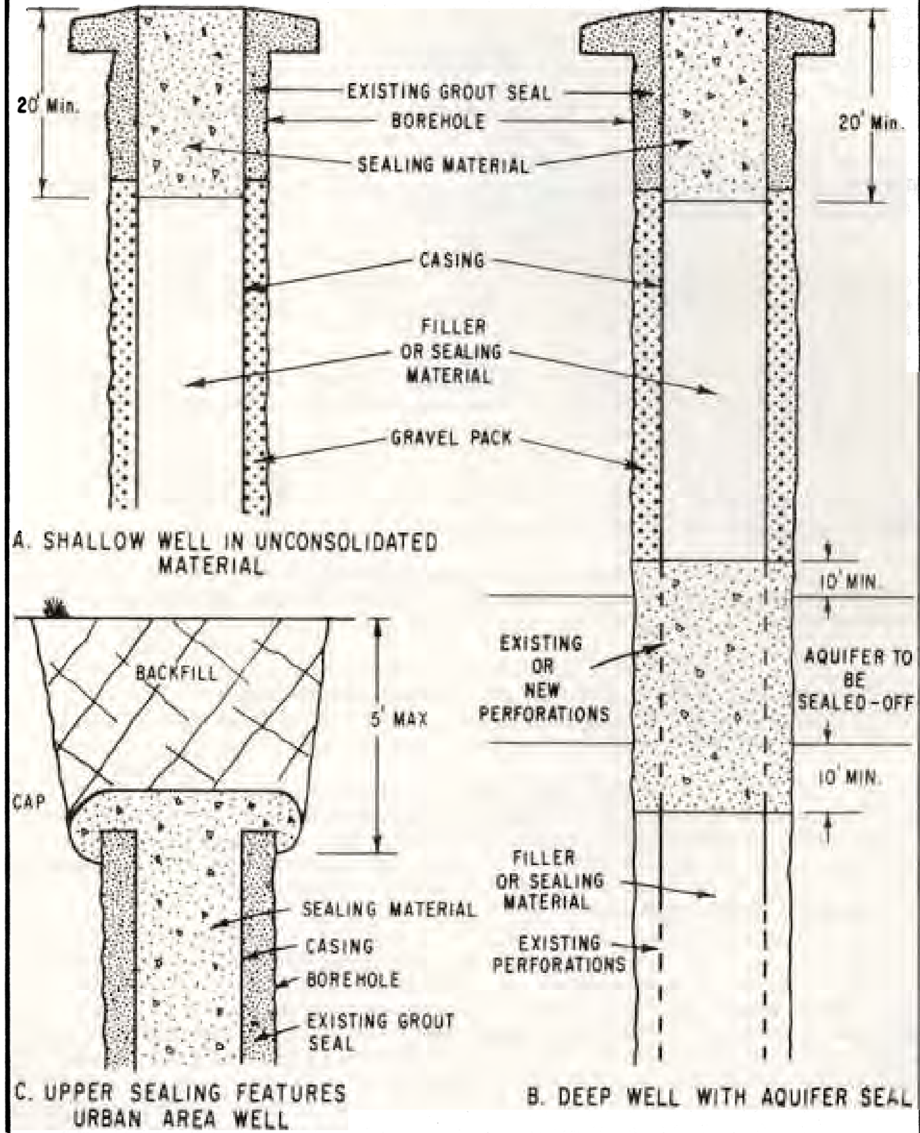

Figure 9. PROPERLY DESTROYED WELLS

3. Well penetrating creviced or fractured rock. If creviced or fractured rock formations are encountered just below the surface, the portions of the well oposite this formation shall be sealed with neat cement, sand-cement grout, or concrete. If these formations extend to considerable depth, alternate layers of coarse stone1/ 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 (6.1 metres) 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.

C. 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 D of this section) from the bottom of the well up.

2. Where neat cement grout, sand-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 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 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.

1/ The limiting dimensions of coarse stone are usually considered to range between 1/4 and 4 inches (6.3 to 100 millimetres).

7. To assure that the well is filled and 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.

D. 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 impervious materials include neat cement, sand-cement grout, concrete, and bentonite clay, all of which are described in Section 9, paragraph D, "Sealing Material" of these standards; and well-proportioned mixes of silts, sands, and clays (or cement), and native soils that have a coefficient of permeability of less than 10 feet (3 metres) per year.1/ Used drilling muds are not acceptable.

2. Filler 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.

E. 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 (see Figure 9C):

1. A hole shall be excavated around the well casing to a depth of 5 feet (1.5 metres) below the ground surface and the well casing removed to 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.

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.

F. 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.

1/ 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.

APPENDIX

DEFINITION OF TERMS

APPENDIX A

DEFINITION OF TERMS

The following terms are defined as used in this report:

Abandoned Well - A well whose use has been permanently discontinued or which is in such a state of disrepair that no water can be produced. Because abandonment is a state that also involves intent on the part of the well owner, a definition that prescribes a set of conditions and a time limit for use in applying standards appears in Section 21 of Chapter II, "Standards", of this report.

Active Well - An operating water well.

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

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

Artesian Well - A well which obtains its water from a confined aquifer. The water level in an artesian well stands some distance above the top of the aquifer it taps. Where the pressure is sufficient to force the water level above the surface of the ground, the well is termed a flowing artesian well.

Bailer - A long narrow bucket with a valve in the bottom used to remove cuttings or fluids from a well.

Bentonite - A highly plastic colloidal clay composed largely of montmorillonite used as a drilling fluid additive or as a sealant.

Casing - A tubular retaining structure which is installed in the well bore to maintain the well opening.

Clay - A fine-grained geologic material (grain size less than 0.004 mm in diameter) which has very low permeability.

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

Cone of Depression - A depression in the water table or piezometric surface of a ground water body that is in the shape of an inverted cone and develops around a well which is being pumped. It defines the area of influence of the pumping well.

Confined Ground Water - Ground water under pressure whose upper surface is the bottom of an impermeable bed or a bed of distinctly lower permeability than the material in which the confined water occurs. Confined ground water moves under the control of the difference in head between the intake and discharge areas of the 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. Usually applies only to water found in geologically older formations.

Consolidated Material - A geologic material whose particles are stratified, cemented, or firmly packed together; usually occurs at depth, e.g., sandstone.

Contamination - Defined in Section 13050 of the California Water Code:

> "(k) 'Contamination' means an impairment of the quality of the waters of the state by waste to a degree which creates a hazard to the public health through poisoning or through the spread of disease. 'Contamination' shall include any equivalent effect resulting from the disposal of waste, whether or not waters of the state are affected."

Destroyed Well - A well that has been properly filled so that it cannot produce water nor act as a vertical conduit for the movement of ground water.

Deterioration - An impairment of water quality.

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

Driller's Mud - A fluid composed of water and clay used in the drilling (primarily rotary) operation. The mud serves 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 the 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.

Gravel Packed Well - A well in which filter material (sand, gravel, etc.) is placed in the annular space between the casing and the borehole to increase the effective diameter of the well, and to prevent fine-grained material from entering the well during pumping.

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 storing or 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 of a consistency that can be forced through a pipe and placed as required. Various additives, such as sand, bentonite, and hydrated lime, are used 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 - That property of a geologic material that renders it incapable of allowing water to move through it perceptibly under the pressure differences ordinarily found in subsurface water.

Impervious Strata - A geologic unit which will not transmit water in sufficient quantity to furnish an appreciable supply to wells or springs.

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

Packer - A device used to plug or seal a well at a specific point; frequently used as retainers to keep grout in position until it "sets".

Perforations - Openings in a well casing to allow the entrance of ground water into the well. Perforations may be made either before or after installation of the casing.

Permeability - The capacity of a geologic material for transmitting a fluid. The degree of permeability depends upon the size and shape of the openings and the extent of the interconnections.

Pollution - Defined in Section 13050 of the California Water Code:

> "(l) 'Pollution' means an alteration of the quality of the waters of the state by waste to a degree which unreasonably affects: (1) such waters for beneficial uses, or (2) facilities which serve such beneficial uses. 'Pollution' may include 'contamination'."

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

Quality of Water or Water Quality — Defined in Section 13050 of the California Water Code:

> "(g) 'Quality of the water' or 'quality of the waters' refers to chemical, physical, biological, bacteriological, radiological, and other properties and characteristics of water which affect its use."

Screen or Well Screen - A factory-perforated casing used in a well that maximizes the entry of water from the producing zone and minimizes the entrance of sand.

Tremie - A tubular device or pipe used to place grout in the annular space. Originally designed for placing concrete under water, the discharge end of the tube is kept submerged in the freshly deposited grout so as not to break the seal while filling the annular space.

Unconfined (free) Ground Water - Ground water that has a free water table, i.e., water not confined under pressure beneath relatively impermeable rocks.

Unconsolidated Material - A sediment that is loosely arranged or unstratified, or whose particles are not cemented together occurring either at the surface or at depth.

Waste - Defined in Section 13050 of the California Water Code:

> "(d) 'Waste' includes sewage and any/all other waste substances, liquid, solid, gaseous, or radioactive, associated with human habitation, or of human or animal origin, or from any producing, manufacturing, or processing operation of whatever nature, including such waste placed within containers of whatever nature prior to, and for purposes of, disposal."

APPENDIX B

SUGGESTED METHODS FOR SEALING THE ANNULAR SPACE AND FOR SEALING-OFF STRATA

Sealing should be accomplished in one continuous operation. Where the sealing interval will exceed 100 feet (30.5 metres) in length, consideration must be given to the collapse strength of the casing. Further, because of the weight of such extensive seals, consideration must also be given to the installation of stronger retaining devices and to staging the placement of the seal (as, for example, the installation of a short segment of rapid-setting sealant in advance of the main body of sealing material; the former becomes a foundation to support the extensive seal).

Sealing Methods

The following methods can be used to seal the upper portion of the annular space. Except for the first, these methods are illustrated on Figure 10. The first method is frequently used where short seals, under 20 feet (6 metres) deep, are placed in dry material.

Gravity Installation (Without Tremie). In this method sealing material is poured into the annular space without the use of a tremie or grout pipe. It cannot be used where the annular space contains water and is limited to intervals less than 30 feet (9 metres) deep. When used, visual observation (with the aid of a mirror or light) should be made during placement of the seal.

Grout Pipe Method. In this method, the seal is placed in the annular space by gravity through a grout pipe (or tremie) suspended in the annular space (see Figure 10).

1. Drill the hole large enough to accommodate the grout pipe (at least 4 inches or 100 millimetres, greater in diameter than the diameter of the casing).

2. In caving formations, install a conductor casing.

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

4. Extend the grout pipe down the annular space between the casing and the wall or conductor to near 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. The bottom end of the grout pipe should remain submerged in the sealing material during the entire time it is being placed. The grout pipe is gradually withdrawn as the sealing material is placed. Where a conductor casing is used to hold back caving material, it may be withdrawn as the sealing material is placed.

Pumping-Exterior Placement. For this method the same procedure as described for the Grout Pipe Method (above) is followed except that the material is placed by pumping instead of by gravity flow. The grout pipe must always be full of sealing material and its bottom end must remain submerged in the sealing material until the interval has been filled.

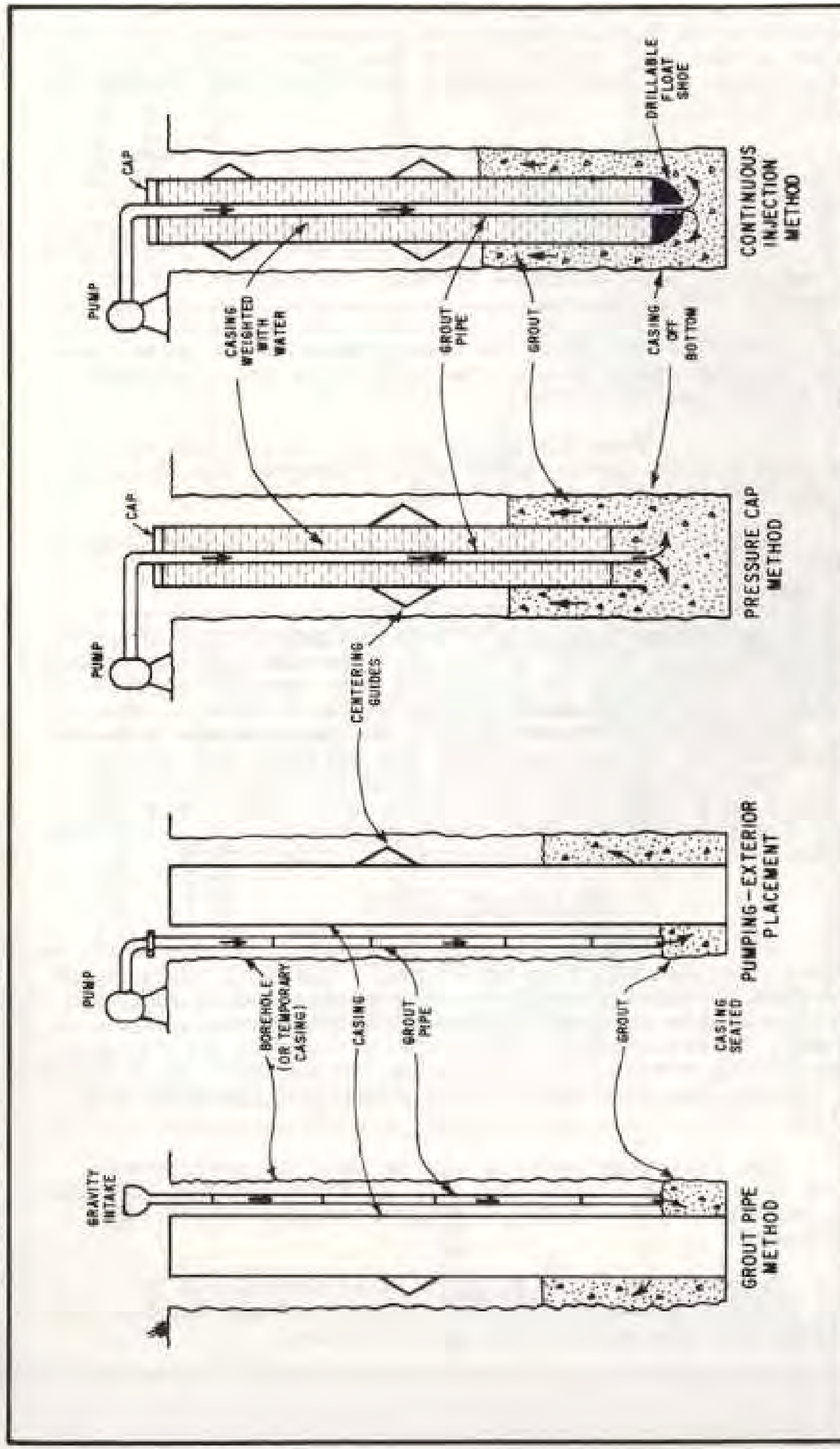

Figure 10. METHODS FOR SEALING THE ANNULAR SPACE

Pressure Cap Method. In the pressure cap method, the grouting is done with the hole drilled about 2 feet (0.6 metre) below the bottom of the conductor casing and the remainder of the well drilled after the grout is in place and set. The grout is placed through a grout pipe set inside the conductor casing.

1. The casing is suspended about 2 feet (0.6 metre) above the bottom of the drilled hole and filled with water.

2. A pressure cap is placed over the conductor 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 conductor casing, to the ground surface.

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

Because there is the possibility that coarse aggregate will "jam" the grout pipe, concrete cannot be used as a sealant when this method is used.

Continuous Injection. This method, called the Normal Displacement Method in the oil industry (which developed it), involves pumping grout through a tube or pipe centered in the casing via a "float shoe" fitted at the bottom of the casing. The grout is forced up into the annular space to the ground surface as is the case with the pressure cap method (above). The tube is detached and flushed. The float shoe, which has a back pressure valve, is drilled out. Because there is the possibility that coarse aggregate will "jam" the grout pipe, concrete cannot be used with this method.

Sealing-off Strata

When the hole for a well is drilled, a strata may be found that produces water of undesirable quality. To prevent the movement of this water into other strata and to maintain the quality of the water to be produced by the well, such strata must be sealed-off. Also, where a highly porous non-water producing strata is encountered, it too must be sealed-off to prevent the loss of water or hydraulic pressure from the well.

The following methods can be used in sealing-off strata or zones (see Figure 11). In addition, several of the methods described for sealing the upper annular space can also be used.

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

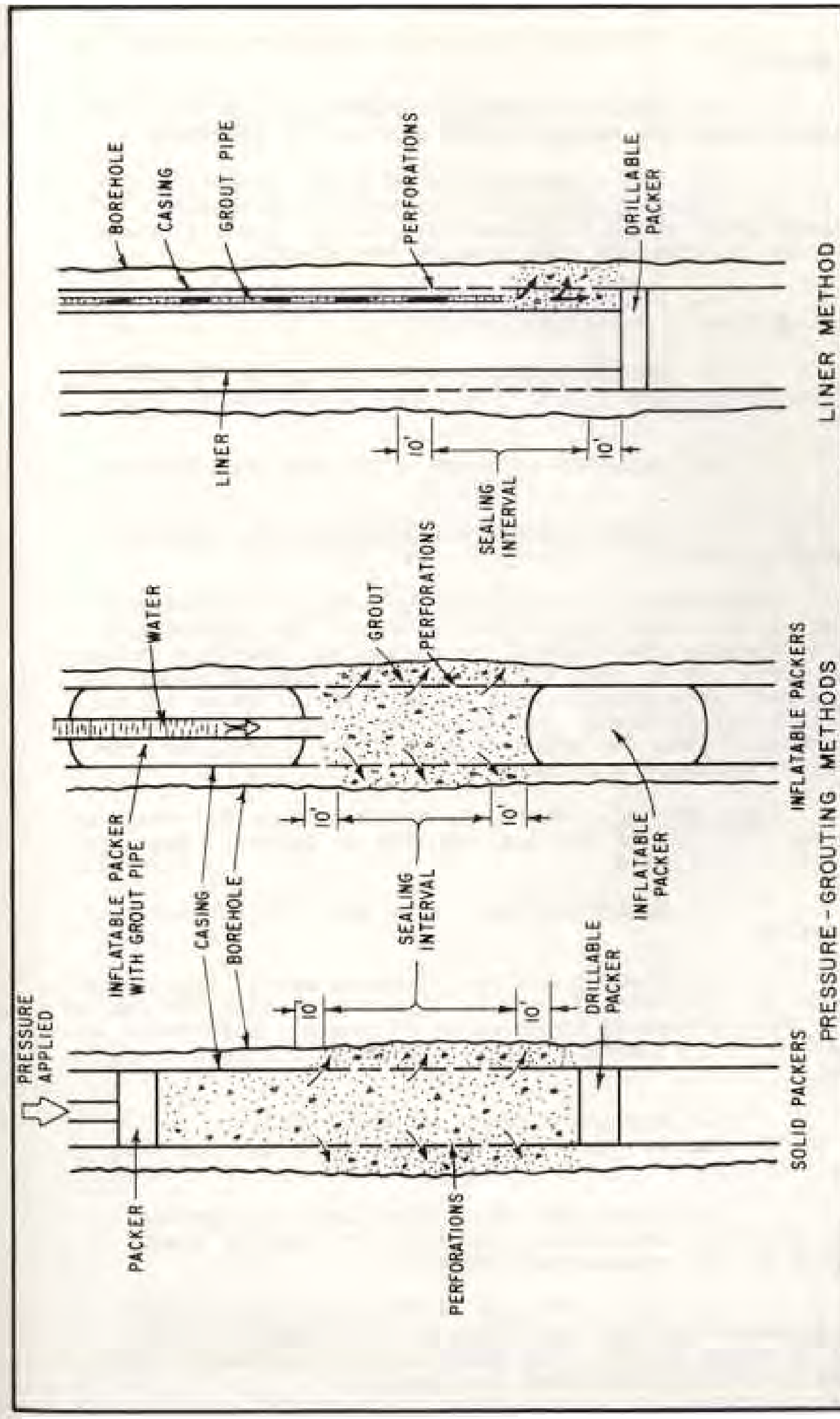

Figure 11. METHODS FOR SEALING-OFF STRATA

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. Use a dump bailer or grout pipe to place grout in the casing opposite the interval to be sealed. Sufficient grout shall be placed to fill the annular space and extend out into the strata to be sealed-off.

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 packers and other material remaining in the well.

Frequently, an assembly consisting of inflatable (balloon) packers and grout pipe is used. The packers are placed to enclose the interval to be sealed, they are inflated and the grout pumped down the hose (which passes through the upper packer) into the 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 the annular space between the casing and the wall of the drilled hole is minimal, the liner method can be employed.

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

2. Place a smaller diameter metal liner, about 2 inches (50 millimetres) less in diameter, inside the casing opposite the perforated interval to be sealed, and extend it at least 10 feet (3 metres) above and below the perforated interval.

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

4. Extend the grout pipe into the opening between the liner and casing, and fill the annular space with grout in one continuous operation.

5. The botton end of the grout pipe should remain submerged in the sealing material during the entire time it is being placed. The grout pipe is gradually withdrawn as the sealing material is placed.

APPENDIX C

SUGGESTED PROCEDURES FOR DISINFECTING WELLS

APPENDIX C

SUGGESTED PROCEDURES FOR DISINFECTING WELLS

Disinfection of all wells is recommended to eliminate pathogenic organisms as well as organisms that can grow in wells and thereby cause clogging and effect the quality of water produced. Disinfection of the well is the final act of well construction or repair before it is placed in service. Wells should also be disinfected following repair or replacement of the pump and/or well maintenance. The procedures described in this appendix are recommended for disinfecting wells; however, other methods may be used provided it can be demonstrated that they will yield comparable results. For new wells, disinfection should take place following development (this will assure that the well is purged of drilling mud, dirt and other debris that reduces the effectiveness of the disinfection), testing for yield, and installation of the pump. When there is a delay in pump installation, interim or partial disinfection should be undertaken.

Disinfection involves seven steps:

1. A chlorine solution containing at least 50 mg/l (or parts per million) available chlorine, is added to the well. Table 6 lists quantities of various chlorine compounds required to dose 100 feet (30 metres) of water-filled casing at 50 mg/l for diameters ranging from 2 to 24 inches (50 to 600 millimetres). For wells that have been repaired or when the pump has been repaired or replaced and, bringing the well back into service quickly is desired, the solution should contain at least 100 mg/l available chlorine. To obtain this concentration, double the amounts shown in Table 6.

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 turned on and off several times (i.e., "surged") 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.

COLLECTION OF WATER QUALITY SAMPLES

APPENDIX D

COLLECTION OF WATER QUALITY SAMPLES

Water from all new wells should be sampled in order to determine the quality of the water that is being produced. The type of analysis that will be made is dependent on the expected use of the water. For example, individual domestic wells should be sampled for determination of bacterial quality and chemical quality. The water from agricultural wells is generally examined only for the presence of specific chemicals unless there is the likelihood that there will be incidental domestic use of the water, in which case the bacterial quality ought to be determined too.

Recommendations regarding the types of analyses to be performed for the various uses of water will be found in numerous references on water quality and ground water; however, it is best to consult with local agencies such as county farm advisors, health departments or water service agencies (irrigation or water districts). Sampling of community water supply wells is covered by requirements of the California Department of Health Services.1/

Bacterial Sampling

For individual domestic wells, technical advice regarding the collection of bacteriological samples may be obtained from the local health departments or from the laboratories 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, 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 and into the bottle while it is being filled. If the water is collected from a sample tap, turn on the tap and allow the water to flow for 2 or 3 minutes before collecting the sample.2/ Do not rinse the sample bottle. The sample should be delivered to the laboratory as soon as possible and in no case more than 30 hours after its collection. During delivery, the sample should be kept as cool as possible (but not frozen).

1/ Refer to Section 4026, California Health and Safety Code and Chapter 15, "Domestic Water Quality and Monitoring" of Title 22, California Administrative Code.

2/ An alternative is to sterilize the tap first with a propane torch or similar device.

Chemical Sampling

Generally, a routine mineral analyses (determination of the concentrations of the common minerals such as calcium, sodium, chloride, sulfate, etc.) plus analyses for selected minor elements 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 specified uses it may also be desirable to make analysis for concentrations of certain constituents (such as iron and manganese in the case of domestic water or boron in irrigation water). Organic chemicals are not routinely determined. Information or advice on chemical quality conditions may be obtained from local agencies such as the county farm advisors, health departments, etc.

The sample should be collected after the well has been pumped long enough to remove standing water and development and disinfectant chemicals, and to ensure that water from the producing formation(s) has entered the well. The water sample should be collected in a chemically clean container, preferably one obtained from the laboratory that will 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 and whether or not preservatives are needed. However, one-half gallon (1.9 litres) is usually sufficient for a routine mineral analysis; one gallon (3.8 litres) when analysis for minor elements (i.e., iron, manganese, etc.) is also required. Sample quantities for organic chemicals vary according to the type of analysis, and range from very small amounts up to several gallons (litres). In addition, where organic chemicals are to be determined, special sampling procedures and equipment may be required. This is particularly true for volatile organic compounds.

In all cases the temperature of the water should be determined immediately upon collection of the sample.

APPENDIX E

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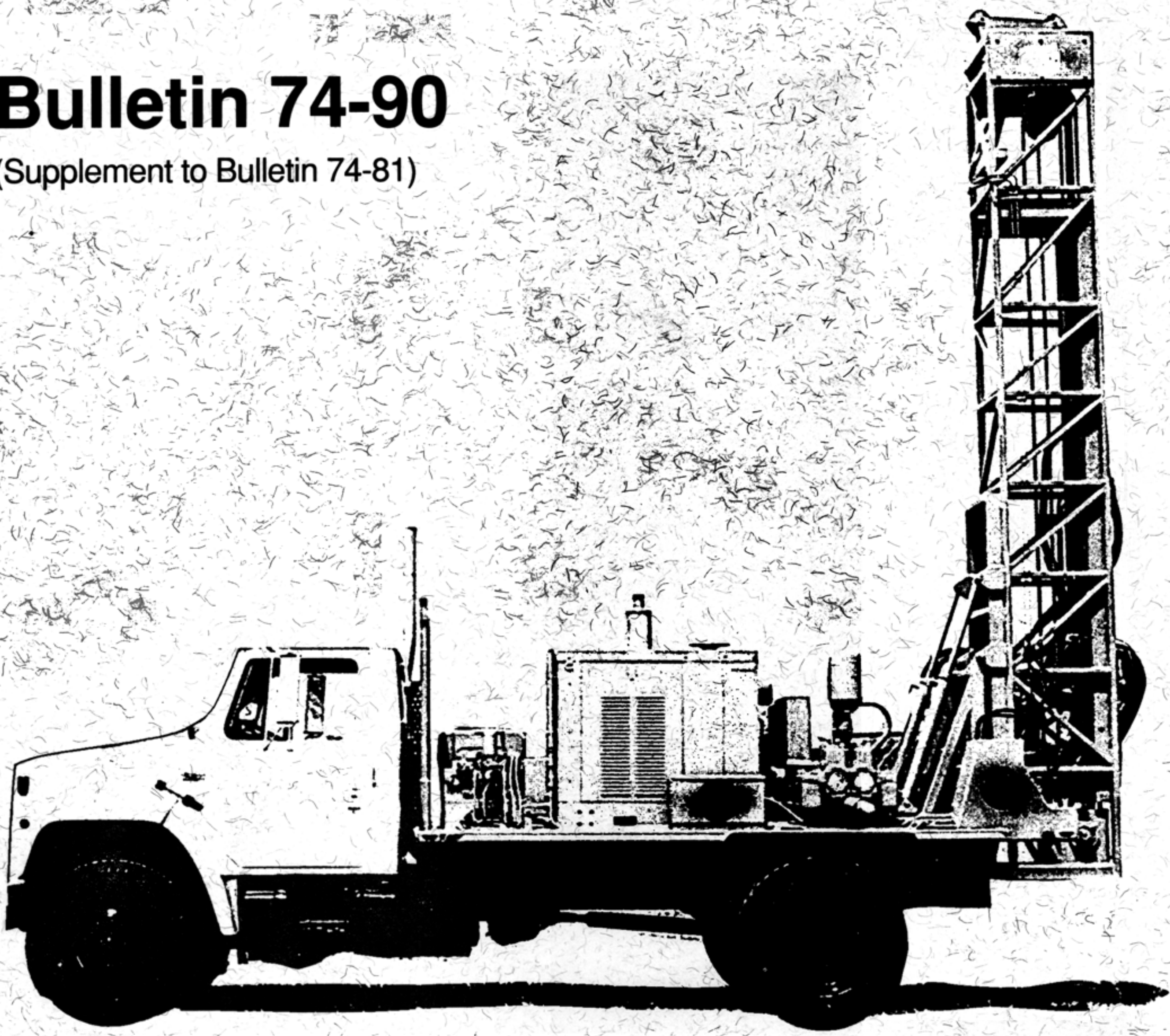
California Well Standards

Water wells • Monitoring wells • Cathodic protection wells

Bulletin 74-90

(Supplement to Bulletin 74-81)



California
Department
of Water Resources
June 1991

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Notice

This Bulletin is temporarily considered to be a draft. The California Department of Water Resources plans to adopt this Bulletin as final after a public review and comment period. The Department will announce in the future when this Bulletin is final. The Department will also announce any changes to this Bulletin. Announcement will be made through the Department's well standards mailing list.

This page should be removed from this Bulletin when it is announced that the Bulletin has been approved as final.

California Well Standards

Water wells • Monitoring wells • Cathodic protection wells

Bulletin 74-90

(Supplement to Bulletin 74-81)

David N. Kennedy
Director
Department of Water Resources

Douglas P. Wheeler
Secretary for Resources
The Resources Agency

Pete Wilson
Governor
State of California

California
Department
of Water Resources
June 1991

FOREWORD

During an average year about forty percent of California's water supply comes from ground water. Ground water is used for agricultural, industrial, domestic, and municipal water supplies. Protecting the quality of California's ground water is essential to California's future.

Improperly constructed wells can allow pollution of ground water to the point that the water is either unusable or it requires expensive treatment. The California Water Code requires the Department of Water Resources (DWR) to develop minimum standards for water wells, monitoring wells, and cathodic protection wells to protect ground water quality.

This bulletin is a supplement to DWR Bulletin 74-81, *Water Well Standards: State of California, December 1981*. Standards in Bulletin 74-81 and this bulletin are **minimum** requirements for construction, alteration, maintenance, and destruction of water wells, monitoring wells, and cathodic protection wells in California.

This bulletin was prepared in cooperation with the State Water Resources Control Board. The Board adopted a model water well, monitoring well, and cathodic protection well ordinance that implements DWR well standards. All California cities and counties, and some water agencies are required to enact local well ordinances that meet or exceed DWR standards, or they must enforce the Board's model ordinance as if it were their own.

Sometimes well standards adopted by local agencies must be more stringent than DWR's statewide standards because of local conditions. Local agencies play a critical role in protecting ground water quality.

Continued cooperation is needed between the public, industry, local agencies, and the State to ensure that these well standards remain adequate and are put into practice. California's water supply future depends on this cooperation.

David N. Kennedy, Director
Department of Water Resources

State of California
PETE WILSON, Governor

The Resources Agency
DOUGLAS P. WHEELER, Secretary for Resources

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In Cooperation with the State Water Resources Control Board

State of California
The Resources Agency
Department of Water Resources
CALIFORNIA WATER COMMISSION

The CALIFORNIA WATER COMMISSION serves as a policy advisory body to the Director of the Department of Water Resources on all California water resource matters. The nine-member citizen commission provides a water resources forum for the people of the State, acts as liaison between the legislative and executive branches of State government, and coordinates federal, State, and local water resources efforts.

CALIFORNIA WELL STANDARDS

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ACKNOWLEDGEMENTS

This bulletin was prepared after consideration of comments and suggestions from public agencies and private parties. State agencies that provided input include:

- State Water Resources Control Board,
- Regional Water Quality Control Boards,
- Department of Health Services, and,
- California Integrated Waste Management Board.

Many comments and suggestions were received from California cities, counties, and water agencies. Private parties that provided input include the California Groundwater Association, individual well contractors, well construction material and equipment suppliers, and consultants. The Department of Water Resources thanks all persons that provided comments during the preparation of this bulletin.

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Improperly constructed, altered, maintained, or destroyed wells are a potential pathway for introducing poor quality water, pollutants, and contaminants to good-quality ground water. The potential for ground water quality degradation increases as the number of wells and borings in an area increases.

Improperly constructed, altered, maintained, or destroyed wells can facilitate ground water quality degradation by allowing:

- Pollutants, contaminants, and water to enter a well bore or casing;
- Poor quality surface and subsurface water, pollutants, and contaminants to move between the casing and borehole wall;
- Poor quality ground water, pollutants, and contaminants to move from one stratum or aquifer to another; and,
- The well bore to be used for illegal waste disposal.

Permanently inactive or "abandoned" wells that have not been properly destroyed pose a serious threat to water quality. They are frequently forgotten and become dilapidated with time, and thus can become conduits for ground water quality degradation. In addition, humans and animals can fall into wells left open at the surface.

History of DWR Standards

The Department of Water Resources has responsibility for developing standards for wells for the protection of water quality under California Water Code Section 231. Water Code Section 231 was enacted in 1949.

Statewide standards for water wells were first formally published in 1968 as DWR Bulletin 74, *Water Well Standards: State of California*. Standards for cathodic protection wells followed in 1973 as Bulletin 74-1, *Cathodic Protection Well Standards: State of California*. Bulletins 74 and 74-1 are now out of print.

A revised edition of Bulletin 74 was published in 1981 as Bulletin 74-81 *Water Well Standards: State of California*. Bulletin 74-81 is enclosed in the back cover of this report.

The law for establishing and implementing well standards was changed significantly in 1986 by Assembly Bill 3127 and Senate Bill 1817 (now Chapters 1152 and 1373, Statutes of 1986). Assembly Bill 3127 (Water Code Section 13801) requires that:

(1) **By September 1, 1989**, the State Water Resources Control Board adopt a model well ordinance implementing DWR standards.

(2) **By January 15, 1990**, all counties and cities, and water agencies where appropriate, adopt a well ordinance that meets or exceeds DWR well standards.

(3) **By February 15, 1990**, the Board's model ordinance is to be enforced by any county, city, or water agency failing to adopt a well ordinance.

Senate Bill 1817 amended the Water Code to specifically include monitoring wells. It was previously assumed that monitoring wells were included in the collective term "well" used in the law.

As a first step in carrying out provisions of the amended law, the State Water Resources Control Board contracted with DWR to:

(1) Review and update water well standards in Bulletin 74-81;

(2) Establish minimum standards for monitoring wells; and,

(3) Update and replace cathodic protection well standards in Bulletin 74-1.

This Bulletin is a supplement to Bulletin 74-81. It was developed to satisfy the Department's contract with SWRCB, to respond to Department responsibilities under the Water Code, and to keep pace with technical advances during the ten-year period following publication of Bulletin 74-81.

An initial draft of this supplement was published in three sections and was sent to interested organizations and individuals for comment during the Fall of 1988. The Department held public hearings in Los Angeles, November 15, 1988 and in Oakland, November 17, 1988 to discuss the draft supplemental standards and receive public comment.

Several sets of written comments for the draft supplemental standards were received by DWR. Written and verbal comments on the standards were reviewed and appropriate changes were incorporated into *Final Draft Bulletin 74-90, California Well Standards; Water Wells, Monitoring Wells, Cathodic Protection Wells; Supplement to Bulletin 74-81*, January 1990.

Final Draft Bulletin 74-90 was published in November 1989 and was sent to interested organizations and individuals for comment. Comments were reviewed and appropriate changes were incorporated into this final bulletin.

Additional discussion on the history of DWR well standards is contained in Bulletin 74-81.

Relationship of DWR Well Standards Publications

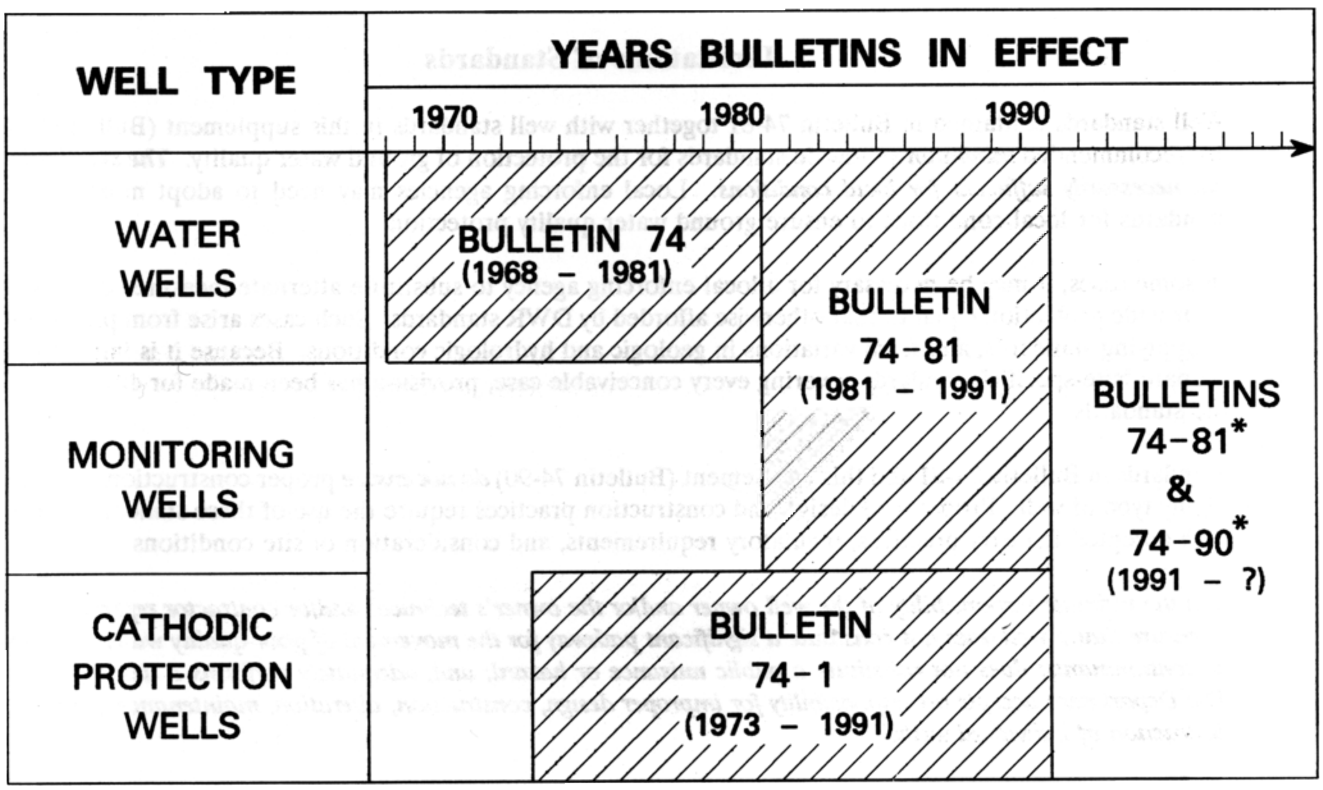
DWR Bulletins 74-81 and 74-1 provided the Department's standards for water wells and cathodic protection wells just prior to this supplement. DWR standards for monitoring wells were generally the same as for water wells prior to this supplement and were included in Bulletin 74-81. The relationship of the various DWR well standards bulletins is illustrated in Figure 1.

Revised standards for water wells in this supplement replace only portions of the water well standards contained in Bulletin 74-81. This supplement is to be used together with Bulletin 74-81 for a complete description of DWR Water Well Standards.

Monitoring well standards are presented separately in this supplement and are in parallel form to the water well standards. Because many physical similarities exist between water wells and monitoring wells, the water well standards are referred to frequently in the monitoring well standards. Water well and monitoring well standards must be considered together for the construction, alteration, maintenance, and destruction of monitoring wells.

Cathodic protection well standards in this supplement replace those in Bulletin 74-1. Because of similarities between cathodic protection wells and water wells, water wells standards are referred to frequently in the cathodic protection well standards. Cathodic protection well standards and water well standards must be considered together for the construction, alteration, maintenance, and destruction of cathodic protection wells.

Figure 1. YEARS DWR WELL STANDARDS BULLETINS IN EFFECT



* Both bulletins are now required for water well, monitoring well, and cathodic protection well standards.

Organization of This Supplement

Standards in this supplement are presented in three parts:

(1) Revisions of some water well standards in Bulletin 74-81.

(2) Standards for monitoring wells.

(3) Updated standards for cathodic protection wells that were originally published in Bulletin 74-1.

Selected technical terms used in this supplement are listed and defined in Appendix A. A list of references is contained in Appendix B.

Limitations of Standards

Well standards contained in Bulletin 74-81 together with well standards in this supplement (Bulletin 74-90) are recommended ***minimum*** statewide standards for the protection of ground water quality. ***The standards are not necessarily sufficient for local conditions.*** Local enforcing agencies may need to adopt more stringent standards for local conditions to ensure ground water quality protection.

In some cases, it may be necessary for a local enforcing agency to substitute alternate measures or standards to provide protection equal to that otherwise afforded by DWR standards. Such cases arise from practicalities in applying standards, and from variations in geologic and hydrologic conditions. Because it is impractical to prepare "site-specific" standards covering every conceivable case, provision has been made for deviation from the standards.

Standards in Bulletin 74-81 and this supplement (Bulletin 74-90) ***do not ensure*** proper construction or function of any type of well. Proper well design and construction practices require the use of these standards together with accepted industry practices, regulatory requirements, and consideration of site conditions.

It is the ultimate responsibility of the well owner and/or the owner's technical and/or contractor representative(s) to ensure that a well does not constitute a significant pathway for the movement of poor-quality water, pollutants, or contaminants; does not constitute a public nuisance or hazard; and, adequately performs a desired function. The Department accepts no responsibility for improper design, construction, alteration, maintenance, function, or destruction of individual wells.

Applicability

Construction standards presented in this supplement apply to all water wells, monitoring wells, and cathodic protection wells constructed after the date of this supplement. Alteration, maintenance, and destruction standards presented in this supplement apply to all water wells, monitoring wells, cathodic protection wells, and "borings" regardless of their original date of construction. Standards contained in Bulletin 74-81 remain in effect except where modified by this supplement (Bulletin 74-90).

WATER WELLS

REVISIONS TO WATER WELL STANDARDS

INTRODUCTION

Revisions to standards in DWR Bulletin 74-81, Chapter II, are presented in this section. All standards in Bulletin 74-81 that are not revised by this supplement (Bulletin 74-90) remain unchanged and in effect. The organization and numbering system used for the revisions is the same as that in Bulletin 74-81.

Table 1, page 10, below, lists portions of Bulletin 74-81 that are replaced by this supplement (Bulletin 74-90). The user of this supplement should strike-out the replaced sections and paragraphs in the copy of Bulletin 74-81 that is enclosed in the back cover of this supplement.

Table 1

Deletions in Bulletin 74-81

Page	Portions of Bulletin 74-81 Replaced by this Supplement, Bulletin 74-90
24	Subsection I
25	Subsections J and L
26	Subsection A of Section 8, and Footnote No. 3
27	Entire Page, Including All Footnotes
29	Entire Page, Including All Footnotes
30	Entire Page, Including All Footnotes
32	Remainder of Item 3
34	Subsection D, and All Footnotes
35	Entire Page, Including All Footnotes
36	Item 2, Item 3, and Item 4
39	Item 5, Subsection B, and All Footnotes
40	Subsection F, and Footnote No. 1
43	Item 3, and Footnote No. 1
44	Remainder of Item 3, and Both Footnotes
45	Item 5, and Item 6, Subsection B, and Both Footnotes
46	Remainder of Subsection B, Section 14
48	Remainder of Section 14
52	Section 21, Footnote No. 2
53	Remainder of Section 21, Item 1
54	Item 1

STANDARDS

Part I. General

Section 1. Definitions.

Definitions A through H, and K (page 23 of Bulletin 74-81) are unchanged. The definition for observation and monitoring wells under Definition I has been deleted and replaced with a definition for "exploration hole." Observation or monitoring wells are now addressed in monitoring well standards in this supplement.

The new definition under Definition I is:

"I. Exploration Hole (or Boring). An uncased, temporary excavation whose purpose is the determination of hydrologic conditions at a site."

Definitions J and L have been revised to read as follows:

"J. Test Wells. Wells constructed to obtain information needed for design of other wells. Test wells should not be confused with "exploration holes", which are temporary. Test wells are cased and can be converted to other uses such as ground water monitoring and, under certain circumstances, to production wells.

L. Enforcing Agency. An agency designated by duly authorized local, regional, or State government to administer and enforce laws or ordinances pertaining to the construction, alteration, maintenance, and destruction of water wells. The California State Department of Health Services or the local health agency is the enforcing agency for community water supply wells."

Sections 2 through 7 (page 25 of Bulletin 74-81) are unchanged.

Part II. Well Construction

Section 8. Well Location With Respect to Pollutants and Contaminants, and Structures.

Note: The title of Section 8 has been revised.

Section 8 (page 26 of Bulletin 74-81) has been revised to read as follows:

"A. Separation. All water wells shall be located an adequate horizontal distance from known or potential sources of pollution and contamination. Such sources include, but are not limited to:

- sanitary, industrial, and storm sewers;
- septic tanks and leachfields;
- sewage and industrial waste ponds;
- barnyard and stable areas;
- feedlots;
- solid waste disposal sites;
- above and below ground tanks and pipelines for storage and conveyance of petroleum products or other chemicals; and,
- storage and preparation areas for pesticides, fertilizers, and other chemicals.

Consideration should also be given to adequate separation from sites or areas with known or suspected soil or water pollution or contamination.

The following horizontal separation distances are generally considered adequate where a significant layer of unsaturated, unconsolidated sediment less permeable than sand is encountered between ground surface and ground water. These distances are based on present knowledge and past experience. Local conditions may require greater separation distances to ensure ground water quality protection.

Potential Pollution or Contamination Source	Minimum Horizontal Separation Distance Between Well and Known or Potential Source
Any sewer line (sanitary, industrial, or storm; main or lateral)	50 feet
Watertight septic tank or subsurface sewage leaching field	100 feet
Cesspool or seepage pit	150 feet
Animal or fowl enclosure	100 feet

If the well is a radial collector well, minimum separation distances shall apply to the furthest extended point of the well.

Many variables are involved in determining the "safe" separation distance between a well and a potential source of pollution or contamination. No set separation distance is adequate and reasonable for all conditions. Determination of the safe separation distance for individual wells requires detailed evaluation of existing and future site conditions.

Where, in the opinion of the enforcing agency adverse conditions exist, the above separation distances shall be increased, or special means of protection, particularly in the construction of the well, shall be provided, such as increasing the length of the annular seal.

Lesser distances than those listed above may be acceptable where physical conditions preclude compliance with the specified minimum separation distances and where special means of protection are provided. Lesser separation distances must be approved by the enforcing agency on a case-by-case basis.

B. Gradients. Where possible, a well shall be located up the ground water gradient from potential sources of pollution or contamination. Locating wells up gradient from pollutant and contaminant sources can provide an extra measure of protection for a well. However, consideration should be given that the gradient near a well can be reversed by pumping, as shown in Figure 3 (page 28 of Bulletin 74-81), or by other influences.

C. Flooding and Drainage. If possible, a well should be located outside areas of flooding. The top of the well casing shall terminate above grade and above known levels of flooding caused by drainage or runoff from surrounding land. For community water supply wells, this level is defined as the:

> "...floodplain of a 100 year flood..." or above "...any recorded high tide...", (Section 64417, *Siting Requirements*, Title 22 of the California Code of Regulations.)

If compliance with the casing height requirement for community water supply wells and other water wells is not practical, the enforcing agency shall require alternate means of protection.

Surface drainage from areas near the well shall be directed away from the well. If necessary, the area around the well shall be built up so that drainage moves away from the well.

D. Accessibility. All wells shall be located an adequate distance from buildings and other structures to allow access for well modification, maintenance, repair, and destruction, unless otherwise approved by the enforcing agency."

Section 9. Sealing the Upper Annular Space.

***Note*:** Sealing requirements are also described in Appendix B, page 67 of Bulletin 74-81.

Section 9 (page 29 of Bulletin 74-81) has been revised to read as follows:

"The space between the well casing and the wall of the drilled hole, often referred to as the annular space, shall be effectively sealed to prevent it from being a preferential pathway for movement of poor-quality water, pollutants, or contaminants. In some cases, secondary purposes of an annular seal are to protect casing against corrosion or degradation, ensure the structural integrity of the casing, and stabilize the borehole wall.

A. Minimum Depth of Annular Surface Seal. The annular surface seal for various types of water wells shall extend from ground surface to the following minimum depths:

Well Type	Minimum Depth Seal Must Extend Below Ground Surface
Community Water Supply	50 feet
Industrial	50 feet
Individual Domestic	20 feet
Agricultural	20 feet
Air-Conditioning	20 feet
All Other Types	20 feet

1. Shallow ground water. Exceptions to minimum seal depths can be made for shallow wells at the approval of the enforcing agency, where the water to be produced is at a depth less than 20 feet. In no case shall an annular seal extend to a total depth less than 10 feet below land surface. The annular seal shall be no less than 10 feet in length.

   Caution shall be given to locating a well with a 'reduced' annular seal with respect to sources of pollution or contamination. Such precautions include horizontal separation distances greater than those listed in Section 8, page 12, above.

2. Encroachment on known or potential sources of pollution or contamination. When, at the approval of the enforcing agency, a water well is to be located closer to a source of pollution or contamination than allowed by Section 8, page 12, above, the annular space shall be sealed from ground surface to the first impervious stratum, if possible. The annular seal for all such wells shall extend to a minimum depth of 50 feet.

3. Areas of freezing. The top of an annular surface seal may be below ground surface in areas where freezing is likely, but in no case more than 4 feet below ground surface. 'Freezing' areas are those where the mean length of the freeze-free period described by the National Weather Service is less than 100 days. In other words, 'freezing' areas are where temperatures at or below 32 degrees Fahrenheit are likely to occur on any day during a period of 265 or more days each year. In general, these areas include:

   portions of Modoc, Lassen, and Siskiyou Counties;

   - portions of the North Lahontan area including the eastern slope of the Sierra Nevada and related valleys north of Mount Whitney and Mono Lake; and,

   - the area of Lake Arrowhead in the San Bernardino Mountains.

4. Vaults. At the approval of the enforcing agency, the top of an annular surface seal and well casing can be below ground surface where traffic or other conditions require, if the seal and casing extend to a watertight and structurally sound subsurface vault, or equivalent feature. In no case shall the top of the annular surface seal be more

than 4 feet below ground surface. The vault shall extend from the top of the annular seal to at least ground surface.

The use of subsurface vaults to house the top of water wells below ground surface is rare and is discouraged due to susceptibility to the entrance of surface water, pollutants, and contaminants. Where appropriate, pitless adapters should be used in place of vaults.

B. Sealing Conditions. The following requirements are to be observed for sealing the annular space.

1. Wells drilled in unconsolidated, caving material. An 'oversized' hole, at least 4 inches greater in diameter than the outside diameter of the well casing, shall be drilled and a conductor casing temporarily installed to at least the minimum depth of annular seal specified in Subsection A, page 14, above. Permanent conductor casing may be used if it is installed in accordance with Item 3, page 16, below, and Item 5 (page 32 of Bulletin 74-81) and if it extends at least to the depth specified in Subsection A, above. One purpose of conductor casing is to hold the annular space open during well drilling and during the placement of the well casing and annular seal.

Temporary conductor casing shall be withdrawn as sealing material is placed between the well casing and borehole wall, as shown in Figure 4A (page 31 of Bulletin 74-81). Sealing material shall be placed at least within the interval specified in Subsection A, above. The sealing material shall be kept at a sufficient height above the bottom of the temporary conductor casing as it is withdrawn to prevent caving of the borehole wall.

Temporary conductor casing may be left in place in the borehole after the placement of the annular seal only if it is impossible to remove because of unforeseen conditions and not because of inadequate drilling equipment, or if its removal will seriously jeopardize the integrity of the well and the integrity of subsurface barriers to pollutant or contaminant movement. Temporary conductor casing may be left in place only at the approval of the enforcing agency on a case-by-case basis.

Every effort shall be made to place sealing material between the outside of temporary conductor casing that cannot be removed and the borehole wall to fill any possible gaps or voids between the conductor casing and the borehole wall. At least two inches of sealing material shall be maintained between the conductor casing and well casing. At a minimum, sealing material shall extend through intervals specified in Subsection A, above.

Sealing material can often be placed between temporary conductor casing that cannot be removed and the borehole wall by means of pressure grouting techniques, as described below and in Appendix B (page 67 of Bulletin 74-81). Other means of placing sealing material between the conductor casing and the borehole wall can be used, at the approval of the enforcing agency.

Pressure grouting shall be accomplished by perforating temporary conductor casing that cannot be removed, in place. The perforations are to provide passages for sealing material to pass through the conductor casing to fill any spaces and voids between the casing and borehole wall. Casing perforations shall be a suitable size and density to allow the passage of sealing materials through the casing and the proper distribution of sealing material in spaces between the casing and borehole wall. At a minimum, the perforations shall extend through the intervals specified in Subsection A, above, unless otherwise approved by the enforcing agency.

Temporary conductor casing that must be left in place shall be perforated immediately before sealing operations begin to prevent drilling or well construction operations from clogging casing perforations. Once the casing has been adequately perforated, sealing material shall be placed inside the conductor casing and subjected to sufficient pressure to cause the sealing material to pass through the conductor casing perforations and completely fill any spaces or voids between the casing and borehole wall, at least within the intervals specified in Subsection A, above. Sealing material shall consist of neat cement, or bentonite prepared from powdered bentonite and water, unless otherwise approved by the enforcing agency.

Sealing material must also fill the annular space between the conductor casing and the well casing within required sealing intervals.

2. <u>Wells drilled in unconsolidated material with significant clay layers</u>. An 'oversized' hole, at least 4 inches greater in diameter than the outside diameter of the well casing, shall be drilled to at least the depth specified in Subsection A, page 14, above, and the annular space between the borehole wall and the well casing filled with sealing material in accordance with Subsection A, above (see Figure 4B, page 31 of Bulletin 74-81). If a significant layer of clay or clay-rich deposits of low permeability is encountered within 5 feet of the minimum seal depth prescribed in Subsection A, above, the annular seal shall be extended at least 5 feet into the clay layer. Thus, the depth of seal could be required to be extended as much as another 10 feet. If the clay layer is less than 5 feet in total thickness, the seal shall extend through its entire thickness.

   If caving material is present within the interval specified in Subsection A, a temporary conductor casing shall be installed to hold the borehole open during well drilling and placement of the casing and annular seal, in accordance with the requirements of Item 1, page 15, above. Permanent conductor casing may be used if it is installed in accordance with Item 3, below and Item 5 (page 32 of Bulletin 74-81) and it extends to at least the depth specified in Subsection A, above.

3. <u>Wells drilled in soft consolidated formations (extensive clays, sandstones, etc.)</u>. An 'oversized' hole, at least 4 inches greater in diameter than the outside diameter of the well casing, shall be drilled to at least the depth specified in Subsection A, page 14, above. The space between the well casing and the borehole shall be filled with sealing material to at least the depth specified in Subsection A, above, as shown by Figure 4C (page 31 of Bulletin 74-81).

   If a permanent conductor casing is to be installed to facilitate the construction of the well, an oversized hole, at least 4 inches greater in diameter than the outside surface of the permanent conductor casing, shall be drilled to the bottom of the conductor casing or to at least the depth specified in Subsection A, above, and the annular space between the conductor casing and the borehole wall filled with sealing material. In some cases, such as in cable tool drilling, it may be necessary to extend permanent conductor casing beyond the depth of the required depth of the annular surface seal in order to maintain the borehole. Sealing material is not required between conductor casing and the borehole wall other than the depths specified in Subsection A, above, and Section 13, below (page 46 of Bulletin 74-81)."

Items 4 through 7 (page 32 of Bulletin 74-81) are unchanged. Item 8 has been added, as follows:

"8. Wells that penetrate zones containing poor-quality water, pollutants, or contaminants. If geologic units or fill known or suspected to contain poor-quality water, pollutants, or contaminants are penetrated during drilling, and, the possibility exists that poor-quality water, pollutants, or contaminants could move through the borehole during drilling and well construction operations and significantly degrade ground water quality in other units before sealing material can be installed, then precautions shall be taken to seal off or 'isolate' zones containing poor-quality water, pollutants, and contaminants during drilling and well construction operations. Special precautions could include the use of temporary or permanent conductor casing, borehole liners, and specialized drilling equipment. The use of conductor casing is described in Item 1, page 15, above."

Subsection C (page 34 of Bulletin 74-81) is unchanged. Subsections D, E, and F (page 34 of Bulletin 74-81) have been changed to read as follows:

"D. Sealing Material. Sealing material shall consist of neat cement, sand cement, concrete, or bentonite. Cuttings from drilling, or drilling mud, shall not be used for any part of the sealing material.

1. Water. Water used to prepare sealing mixtures should generally be of drinking water quality, shall be compatible with the type of sealing material used, be free of petroleum and petroleum products, and be free of suspended matter. In some cases water considered nonpotable, with a maximum of 2,000 milligrams per liter chloride and 1,500 mg/l sulfate, can be used for cement-based sealing mixtures. The quality of water to be used for sealing mixtures shall be determined where unknown.

2. Cement. Cement used in sealing mixtures shall meet the requirements of American Society for Testing and Materials C150, *Standard Specification for Portland Cement*, including the latest revisions thereof.

Types of Portland cement available under ASTM C150 for general construction are:

Type I - General purpose. Similar to American Petroleum Institute Class A.

Type II - Moderate resistance to sulfate. Lower heat of hydration than Type I. Similar to API Class B.

Type III - High early strength. Reduced curing time but higher heat of hydration than Type I. Similar to API Class C.

Type IV - Extended setting time. Lower heat of hydration than Types I and III.

Type V - High sulfate resistance.

Special cement setting accelerators and retardants and other additives may be used in some cases. Special field additives for Portland cement mixtures shall meet the requirements of ASTM C494, *Standard Specification for Chemical Admixtures for Concrete*, and latest revision thereof.

Hydrated lime may be added up to 10 percent of the volume of cement used to make the seal mix more fluid. Bentonite may be added to cement-based mixes, up to 6 percent by weight of cement used, to improve fluid characteristics of the sealing mix and reduce the rate of heat generation during setting.

Dry additives should be mixed with dry cement before adding water to the mixture to ensure proper mixing, uniformity of hydration, and an effective and homogeneous seal. The water demand of additives shall be taken into account when water is added to the mix.

Minimum times required for sealing materials containing Portland cement to set and begin curing before construction operations on a well can be resumed are:

- Types I and II cement - 24 hours
- Type III cement - 12 hours
- Type V cement - 6 hours

Type IV cement is seldom used for annular seals because of its extended setting time.

Allowable setting times may be reduced or lengthened by use of accelerators or retardants specifically designed to modify setting time, at the approval of the enforcing agency.

More time shall be required for cement-based seals to cure to allow greater strength when construction or development operations following the placement of the seal may subject casing and sealing materials to significant stress. Subjecting a well to significant stress before a cement-based sealing material has adequately cured can damage the seal and prevent proper bonding of cement-based sealants to casing(s).

If plastic well casing is used, care shall be exercised to control the heat of hydration generated during the setting and curing of cement in an annular seal. Heat can cause plastic casing to weaken and collapse. Heat generation is a special concern if thin-wall plastic well casing is used, if the well casing will be subject to significant net external pressure before the setting of the seal, and/or if the radial thickness of the annular seal is large. Additives that accelerate cement setting also tend to increase the rate of heat generation during setting and, thus, should be used with caution where plastic casing is employed.

The temperature of a setting cement seal can be lowered by circulating water inside the well casing and/or by adding bentonite to the cement mixture, up to 6 percent by weight of cement used.

Cement-based sealing material shall be constituted as follows:

a. Neat Cement. For Types I or II Portland cement, neat cement shall be mixed at a ratio of one 94-pound sack of Portland cement to 5 to 6 gallons of 'clean' water. Additional water may be required where special additives, such as bentonite, or 'accelerators' or 'retardants' are used.

b. Sand Cement. Sand-cement shall be mixed at a ratio of not more than 188 pounds of sand to one 94-pound sack of Portland cement (2 parts sand to 1 part cement, by weight) and about 7 gallons of clean water, where Type I or Type II Portland cement is used. This is equivalent to a '10.3 sack mix.' Less water shall be used if less sand than 2 parts sand per one part cement by weight is used. Additional water may be required when special additives, such as bentonite, or 'accelerators' or 'retardants' are used.

c. Concrete. Concrete is often useful for large volume annular seals, such as in large-diameter wells. The proper use of aggregate can decrease the permeability of the annular seal, reduce shrinkage, and reduce the heat of hydration generated by the seal.

Concrete shall consist of Portland cement and aggregate mixed at a ratio of at least six-94 pound sacks of Portland cement per cubic yard of aggregate. A popular concrete mix consists of eight-94 pound sacks of Type I or Type II Portland cement per cubic yard of uniform 3/8-inch aggregate.

In no case shall the size of the aggregate be more than 1/5 the radial thickness of the annular seal. Water shall be added to concrete mixes to attain proper consistency for placement, setting, and curing.

d. Mixing. Cement-based sealing materials shall be mixed thoroughly to provide uniformity and ensure that no 'lumps' exist.

Ratios of the components of cement-based sealing materials can be varied depending on the type of cement and additives used. Variations must be approved by the enforcing agency.

3. Bentonite. Bentonite clay in 'gel' form has some of the advantages of cement-based sealing material. A disadvantage is that the clay can sometimes separate from the clay-water mixture.

Although many types of clay mixtures are available, none has sealing properties comparable to bentonite clay. Bentonite expands significantly in volume when hydrated. Only bentonite clay is an acceptable clay for annular seals.

Unamended bentonite clay seals should not be used where structural strength of the seal is required, or where it will dry. Bentonite seals may have a tendency to dry, shrink and crack in arid and semi-arid areas of California where subsurface moisture levels can be low. Bentonite clay seals can be adversely affected by subsurface chemical conditions, as can cement-based materials.

Bentonite clay shall not be used as a sealing material if roots from trees and other deep rooted plants might invade and disrupt the seal, and/or damage the well casing. Roots may grow in an interval containing a bentonite seal depending on surrounding soil conditions and vegetation.

Bentonite-based sealing material shall not be used for sealing intervals of fractured rock or sealing intervals of highly unstable, unconsolidated material that could collapse and displace the sealing material, unless otherwise approved by the enforcing agency. Bentonite clay shall not be used as a sealing material where flowing water might erode it.

Bentonite clay products used for sealing material must be specifically prepared for such use. Used drilling mud and/or cuttings from drilling shall not be used in sealing material.

Bentonite used for annular seals shall be commercially prepared, powdered, granulated, pelletized, or chipped/crushed sodium montmorillonite clay. The largest dimension of pellets or chips shall be less than 1/5 the radial thickness of the annular space into which they are placed.

Bentonite clay mixtures shall be thoroughly mixed with clean water ***prior to placement.*** A sufficient amount of water shall be added to bentonite to allow proper hydration. Depending on the bentonite sealing mixture used, 1 gallon of water should be added to about every 2 pounds of bentonite. Water added to bentonite for hydration shall be of suitable quality and free of pollutants and contaminants.

Bentonite preparations normally require 1/2 to 1 hour to adequately hydrate. Actual hydration time is a function of site conditions and the form of bentonite used. Finely divided forms of bentonite generally require less time for hydration, if properly mixed.

Dry bentonite pellets or chips may be placed directly into the annular space below water, where a short section of annular space, up to 10 feet in length, is to be sealed. Care shall be taken to prevent bridging during the placement of bentonite seal material.

E. Radial Thickness of Seal. A minimum of two inches of sealing material shall be maintained between all casings and the borehole wall, within the interval to be sealed, except where temporary conductor casing cannot be removed, as noted in Subsection B, page 15, above. A minimum of two inches of sealing material shall also be maintained between each casing, such as permanent conductor casing, well casing, gravel fill pipes, etc., in a borehole within the interval to be sealed, unless otherwise approved by the enforcing agency. Additional space shall be provided, where needed, for casings to be properly centralized and spaced and allow the use of a tremie pipe during well construction (if required), especially for deeper wells.

F. Placement of Seal.

Obstructions. All loose cuttings, or other obstructions to sealing shall be removed from the annular space before placement of the annular seal.

2. Centralizers. Well casing shall be equipped with centering guides or 'centralizers' to ensure the 2-inch minimum radial thickness of the annular seal is at least maintained. Centralizers need not be used in cases where the well casing is centered in the borehole during well construction by use of removable tools, such as hollow-stem augers.

The spacing of centralizers is normally dictated by the casing materials used, the orientation and straightness of the borehole, and the method used to install the casing.

Centralizers shall be metal, plastic, or other non-degradable material. Wood shall not be used as a centralizer material. Centralizers must be positioned to allow the proper placement of sealing material around casing within the interval to be sealed.

Any metallic component of a centralizer used with metallic casing shall consist of the same material as the casing. Metallic centralizer components shall meet the same metallurgical specifications and standards as the metallic casing to reduce the potential for galvanic corrosion of the casing.

3. Foundation and Transition Seals. A packer or similar retaining device, or a small quantity of sealant that is allowed to set, can be placed at the bottom of the interval to be sealed before final sealing operations begin to form a foundation for the seal.

A transition seal, up to 5 feet in length, consisting of bentonite, is sometimes placed in the annular space to separate filter pack and cement-based sealing materials. The transition seal can prevent cement-based sealing materials from infiltrating the filter pack. A short interval of fine-grained sand, usually less than 2 feet in length, is sometimes placed between the filter pack and the bentonite transition seal to prevent bentonite from entering the filter pack. Also, fine sand is sometimes used in place of bentonite as the transition seal material.

Fine-sized forms of bentonite, such as granules and powder, are usually employed for transition seals if a transition seal is to be placed above the water level in a well boring. Coarse forms of bentonite, such as pellets and chips, are often used where a bentonite transition seal is to be placed below the water level.

Transition seals should be installed by use of a tremie pipe, or equivalent. However, some forms of bentonite may tend to bridge or clog in a tremie pipe.

Bentonite can be placed in dry form or as slurry for use in transition seals. Water should be added to the bentonite transition seal prior to the placement of cement-based sealing materials where bentonite is dry in the borehole. Care should be exercised during the addition of water to the borehole to prevent displacing the bentonite.

Water should be added to bentonite at a ratio of about 1 gallon for every 2 pounds of bentonite to allow for proper hydration. Water added to bentonite for hydration shall be of suitable quality and free of pollutants and contaminants.

Sufficient time should be allowed for bentonite transition seals to properly hydrate before cement-based sealing materials are placed. Normally, 1/2 to 1 hour is required for proper hydration to occur. Actual time of hydration is a function of site conditions.

The top of the transition seal shall be sounded to ensure that no bridging has occurred during placement.

4. Timing and Method of Placement. The annular space shall be sealed as soon as practical after completion of drilling or a stage of drilling. In no case shall the annular space be left unsealed longer than 14 days following the installation of casing.

Sealing material shall be placed in one continuous operation from the bottom of the interval to be sealed, to the top of the interval. Where the seal is more than 100 feet in length, the deepest portion of the seal may be installed first and allowed to set or partially set. The deep initial seal shall be no longer than 10 feet in length. The remainder of the seal shall be placed above the initial segment in one continuous operation.

Sealing material shall be placed by methods (such as the use of a tremie pipe or equivalent) that prevent freefall, bridging, or dilution of the sealing material, or separation of sand or aggregate from the sealing material. Annular sealing materials shall not be installed by freefall unless the interval to be sealed is dry and no deeper than 30 feet below ground surface.

5. Ground Water Flow. Special care shall be used to restrict the flow of ground water into a well boring while placing material, where subsurface pressure causing the flow of water is significant.

6. Verification. It shall be verified that the volume of sealing material placed at least equals or exceeds the volume to be sealed.

7. Pressure. Pressure required for placement of sealing materials shall be maintained long enough for cement-based sealing materials to properly set."

Section 10. Surface Construction Features.

Subsection A, Item 5; Subsection B; and Subsection F (page 39 of Bulletin 74-81) have been changed. The remainder of Section 10 (page 36 of Bulletin 74-81) is unchanged.

"A. Openings.

5. Bases. A concrete base or pad, sometimes called a pump block or pump pedestal, shall be constructed at ground surface around the top of the well casing and contact the annular seal, unless the top of the casing is below ground surface, as provided by Subsection B, page 23, below.

The base shall be free of cracks, voids, or other significant defects likely to prevent water tightness. Contacts between the base and the annular seal, and the base and the well casing, must be water tight and must not cause the failure of the annular seal or well casing. Where cement-based annular sealing material is used, the concrete base shall be poured before the annular seal has set, unless otherwise approved by the enforcing agency.

The upper surface of the base shall slope away from the well casing. The base shall extend at least two feet laterally in all directions from the outside of the well boring, unless otherwise approved by the enforcing agency. The base shall be a minimum of 4 inches thick.

A minimum base thickness of 4 inches is normally acceptable for small diameter, single-user domestic wells. The base thickness should be increased for larger wells. Shape and design requirements for well pump bases vary with the size, weight, and type of pumping equipment to be installed, engineering properties of the soil on which the base is to be placed, and local environmental conditions. A large variety of base designs have been used. The Vertical Turbine Pump Association has developed a standard base design for large lineshaft turbine pumps. This design consists of a square, concrete pump base whose design is dependent on bearing weight and site soil characteristics.

Where freezing conditions require the use of a pitless adapter, and the well casing and annular seal do not extend above ground surface or into a pit or vault, a concrete base or pad shall be constructed as a permanent location monument for the covered well. The base shall be 3 feet in length on each side and 4 inches in thickness, unless otherwise approved by the enforcing agency. The base shall have a lift-out section, or equivalent, to allow access to the well. The lift-out shall facilitate inspection and repair of the well.

B. Well Pits or Vaults. The use of well pits, vaults, or equivalent features to house the top of a well casing below ground surface shall be avoided, if possible, because of their susceptibility to the entrance of poor-quality water, contaminants and pollutants. Well pits or vaults can only be used if approval is obtained from the enforcing agency. A substitute device, such as a pitless adapter or pitless adapter unit (a variation), should almost always be used in place of a vault or pit.

Pitless adapters and units were developed for use in areas where prolonged freezing occurs, and below ground (frost line) discharges are common. Both the National Sanitation Foundation and Water Systems Council have developed standards for the manufacture and installation of pitless adapters and units. (See Appendix E, Bibliography, page 85 of Bulletin 74-81.)

If a pit or vault is used it shall be watertight and structurally sound. The vault shall extend from the top of the annular seal to at least ground surface.

The vault shall contact the annular seal in a manner to form a watertight and structurally sound connection. Contacts between the vault and the annular seal, and the vault and the well casing, if any, shall not fail or cause the failure of the well casing or annular seal.

Where cement-based annular seal materials are used, the vault shall be set into or contact the annular seal material before it sets, unless otherwise approved by the enforcing agency. If bentonite-based sealing material is used for the annular seal, the vault should be set into the bentonite before it is fully hydrated.

Cement-based sealing material shall be placed between the outer walls of the vault and the excavation into which it is placed to form a proper, structurally sound foundation for the vault, and to seal the space between the vault and excavation.

The sealing material surrounding a vault shall extend from the top of the annular seal to ground surface unless precluded in areas of freezing. If cement-based sealing material is used for both the annular seal and the space between the excavation and vault, the sealing material shall be emplaced in a 'continuous pour'. In other words, cement-based sealing material shall be placed between the vault and excavation and contact the cement-based annular seal before the annular seal has set.

The vault cover or lid shall be watertight but shall allow the venting of gases. The lid shall be fitted with a security device to prevent unauthorized access. The outside of the lid shall be clearly and permanently labeled 'WATER WELL'. The vault and its lid shall be strong enough to support vehicular traffic where such traffic might occur.

The top of the vault shall be set at, or above, grade so that drainage is away from the vault. The top of the well casing contained within the vault shall be covered in accordance with requirements under Subsection A, above, (page 36, Bulletin 74-81) so that water, contaminants, and pollutants that may enter the vault will not enter the well casing. The cover shall be provided with a pressure relief or venting device for gases.

F. Backflow Prevention. All pump discharge pipes not discharging or open to the atmosphere shall be equipped with an automatic device to prevent backflow and/or back siphonage into a well. Specific backflow prevention measures are required for drinking water supply wells, as prescribed in Title 17, Public Health, California Code of Regulations (Sections 7583-7585 and 7601-7605, effective June 25, 1987).

Irrigation well systems, including those used for landscape irrigation, and other well systems that employ, or which have been modified to employ, chemical feeders or injectors shall be equipped with a backflow prevention device(s) approved by the enforcing agency."

Section 12. Casing.

Items 3, 5, and 6 of Subsection A (page 43 of Bulletin 74-81) have been revised. The remainder of Subsection A is unchanged. Subsection B (page 45 of Bulletin 74-81) has been revised. The revisions are as follows:

"A. Casing Material.

3. Plastic. Two basic types of plastic are commonly used for plastic well casing: thermoplastics and thermosets. **Thermoplastics** soften with the application of heat and reharden when cooled. Thermoplastics can be reformed repeatedly using heat and sometimes can unexpectedly deform. Attention should be given to the effect of heat on thermoplastic casing from the setting and curing of cement. Additional discussion on sealing material and heat generation is in Section 9, Subsection D, 'Sealing Material'.

Thermoplastics used for well casing include ABS (acrylonitrile butadiene styrene), PVC (polyvinyl chloride), and SR (styrene rubber). PVC is the most frequently used thermoplastic well casing in California. Styrene rubber is seldom used.

Unlike thermoplastics, **thermoset** plastics cannot be reformed after heating. The molecules of thermoset plastic are 'set' during manufacturing by heat, chemical action, or a combination of both. The thermoset plastic most commonly used for well casing is fiberglass.

Thermoplastics. Thermoplastic well casing shall meet the requirements of ASTM F480, *Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80*, including the latest revision thereof. (*Note*: A 'dimension ratio' is the ratio of pipe diameter to pipe wall thickness.)

Pipe made in Schedule 40 and 80 wall thicknesses and pipe designated according to certain pressure classifications are listed in ASTM F480, as well as casing specials referencing the following ASTM specifications:

(1) ABS Pipe. ASTM D1527, *Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80.*

(2) PVC Pipe. ASTM D1785, *Standard Specification for (Poly Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.*

(3) Pressure-Rated PVC Pipe. ASTM D2241, *Standard Specifications for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series).*

Thermoplastic well casing that may be subject to significant impact stress during or after installation shall meet or exceed the requirements for impact resistance classification set forth in Section 6.5 of ASTM F480. Casing that may be subject to significant impact forces includes, but is not limited to; casing that is installed in large diameter, deep boreholes; and casing through which drilling tools pass following installation of the casing in a borehole.

b. Thermoset Plastics. Thermoset casing material shall meet the following specifications, as applicable, including the latest revisions thereof:

(1) Filament Wound Resin Pipe. ASTM D2996, *Standard Specification for Filament Wound Reinforced Thermosetting Resin Pipe.*

(2) Centrifugally Cast Resin Pipe. ASTM D2997, *Standard Specification for Centrifugally Cast Reinforced Thermosetting Resin Pipe.*

(3) Reinforced Plastic Mortar Pressure Pipe. ASTM D3517, *Standard Specification for Reinforced Plastic Mortar Pressure Pipe.*

(4) Glass Fiber Reinforced Resin Pressure Pipe. AWWA[1] C950, *AWWA Standard for Glass-Fiber-Reinforced Thermosetting-Resin Pressure Pipe.*

c. Drinking Water Supply. All plastic casing used for drinking water supply wells, including community supply well and individual domestic wells, shall meet the provisions of National Sanitation Foundation Standard No. 14, *Plastic Piping Components and Related Materials* and any revision thereof. The casing shall be marked or labeled following requirements in NSF Standard No. 14. Standard No. 14 includes the requirements of ASTM F480.

d. Storage, Handling, and Transportation. Plastic casing shall not be stored in direct sunlight or subjected to freezing temperatures for extended periods of time. Plastic casing shall be stored, handled, and transported in a manner that prevents excessive mechanical stress. Casing shall be protected from sagging and bending, severe impacts and loads, and potentially harmful chemicals.

e. Large Diameter Wells. Because large diameter plastic casing has not been used extensively at depths exceeding 500 feet, special care shall be exercised with its use in deep wells.

5. Unacceptable Casing Materials. Galvanized sheet metal pipe such as 'downspout,' tile pipe, or natural wood shall not be used as well casing.

6. Other Materials. Materials in addition to those described above may be used as well casing, subject to enforcing agency approval."

Subsection B (page 45 of Bulletin 74-81) has been revised as follows:

"B. Casing Installation. All well casing shall be assembled and installed with sufficient care to prevent damage to casing sections and joints. All casing joints above intervals of perforations

[1] American Water Works Association.

or screen shall be watertight. Any perforations shall be below the depths specified in Section 9, Subsection A, page 14, above.

Casing shall be equipped with centering guides or 'centralizers' to ensure the even radial thickness of the annular seal and filter pack.

1. Metallic Casing. Metallic casing may be joined by welds, threads, or threaded couplings. Welding shall be accomplished in accordance with the standards of the American Welding Society or the most recent revision of the American Society of Mechanical Engineers Boiler Construction Code. Metallic casing shall be equipped with a 'drive shoe' at the lower end if it is driven into place.

2. Plastic Casing. Plastic casing may be joined by solvent welding or mechanically joined by threads or other means, depending on the type of material and its fabrication. Solvent cement used for solvent welding shall meet specifications for the type of plastic casing used. Solvent cement shall be applied in accordance with solvent and casing manufacturer instructions. Particular attention shall be given to instructions pertaining to required setting time for joints to develop strength.

   The following specifications for solvent cements and joints for PVC casing shall be met, including the latest revisions thereof:

   a. ASTM D2564, *Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings.*

   b. ASTM D2855, *Standard Practice for Making Solvent-Cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings.*

   Plastic casing or screen shall not be subjected to excessive stress during installation and shall not be driven into place. Care shall be taken to ensure that plastic casing and joints are not subjected to excessive heat from cement-based sealing material.

   A specifically designed adapter shall be used to join plastic casing to metallic casing or screen."

Section 14. Well Development.

Section 14 (page 46 of Bulletin 74-81) has been revised as follows:

"Development, redevelopment, or reconditioning of a well shall be performed with care, by methods that will not damage the well structure or destroy natural barriers to the movement of poor quality water, pollutants, and contaminants.

Acceptable well development, redevelopment, or reconditioning methods include:

- Overpumping;
- Surging or swabbing by use of 'plungers';
- Surging with compressed air;
- Backwashing or surging by alternately starting and stopping a pump;
- Jetting with water;

- Introducing specifically-formulated chemicals into a well; and,
- Combinations of the above.

Hydraulic fracturing (hydrofracturing) is sometimes an acceptable well development and redevelopment method when properly performed. Good quality water shall be used in hydrofracturing. The water shall be disinfected prior to introduction into a well. Material used as 'propping' agents shall be free of pollutants and contaminants, shall be compatible with the use of a well, and shall be thoroughly washed and disinfected prior to placement in a well.

Development, redevelopment, or reconditioning by use of specially designed **explosive charges** is in some cases, another acceptable development method. Explosives shall be used with special care to prevent damage to the well structure and to any natural barriers to the movement of poor-quality water, pollutants, and contaminants. Explosives shall only be used by properly-trained personnel.

Wells subjected to chemicals or explosives during development, redevelopment, or reconditioning operations shall be thoroughly pumped to remove such agents and residues immediately after the completion of operations. Chemicals, water, and other wastes removed from the well shall be disposed of in accordance with applicable local, State, and federal requirements. The enforcing agency should be contacted regarding the proper disposal of waste."

Part III. Destruction of Wells

Section 21. Definition of "Abandoned" Well.

Section 21 (page 52 of Bulletin 74-81) has been revised as follows:

"A well is considered 'abandoned' or permanently inactive if it has not been used for one year, unless the owner demonstrates intention to use the well again. In accordance with Section 24400 of the California Health and Safety Code, the well owner shall properly maintain an inactive well as evidence of intention for future use in such a way that the following requirements are met:

"(1) The well shall not allow impairment of the quality of water within the well and ground water encountered by the well.

(2) The top of the well or well casing shall be provided with a cover, that is secured by a lock or by other means to prevent its removal without the use of equipment or tools, to prevent unauthorized access, to prevent a safety hazard to humans and animals, and to prevent illegal disposal of wastes in the well. The cover shall be watertight where the top of the well casing or other surface openings to the well are below ground level, such as in a vault or below known levels of flooding. The cover shall be watertight if the well is inactive for more than five consecutive years. A pump motor, angle drive, or other surface feature of a well, when in compliance with the above provisions, shall suffice as a cover.

(3) The well shall be marked so as to be easily visible and located, and labeled so as to be easily identified as a well.

(4) The area surrounding the well shall be kept clear of brush, debris, and waste materials."

If a pump has been temporarily removed for repair or replacement, the well shall not be considered 'abandoned' if the above conditions are met. The well shall be adequately covered to prevent injury to people and animals and to prevent the entrance of foreign material, surface water, pollutants, or contaminants into the well during the pump repair period."

Section 23. Requirements for Destroying Wells.

Subsection A, Item 1 (page 53 of Bulletin 74-81) and Subsection B, Item 1, (page 54, of Bulletin 74-81) have been changed. The remainder of Section 23 is unchanged.

Subsection A, Item 1 has been revised as follows:

"1. Obstructions. The well shall be cleaned, as needed, so that all undesirable materials, including obstructions to filling and sealing, debris, oil from oil-lubricated pumps, or pollutants and contaminants that could interfere with well destruction are removed for disposal.

The enforcing agency shall be notified as soon as possible if pollutants and contaminants are known or suspected to be in a well to be destroyed. Well destruction operations may then proceed only at the approval of the enforcing agency.

The enforcing agency should be contacted to determine requirements for proper disposal of materials removed from a well to be destroyed."

Subsection B, Item 1 has been revised as follows:

"1. Wells situated in unconsolidated material in an unconfined ground water zone. In all cases the upper 20 feet of the well shall be sealed with suitable sealing material and the remainder of the well shall be filled with suitable fill, or sealing material. (See Figure 9A, page 55 of Bulletin 74-81.)"

MONITORING WELLS

MONITORING WELL STANDARDS

INTRODUCTION

Ground water monitoring wells are principally used for observing ground water levels and flow conditions, obtaining samples for determining ground water quality, and for evaluating hydraulic properties of water-bearing strata. Monitoring wells are sometimes referred to as "observation wells."

The quality of water intercepted by a monitoring well can range from drinking water to highly polluted water. In contrast, production or "water wells" are usually designed to obtain water from productive zones containing good-quality water.

The screen or perforated section of a monitoring well usually extends only a short length to obtain water from, or to monitor conditions within, an individual water-bearing unit or zone. Water wells are often designed to obtain water from multiple water-bearing strata. Although there are usually differences between the design and function of monitoring wells and water wells, water wells sometimes are used as monitoring wells, and vice versa.

Monitoring wells, along with other types of wells, can provide a pathway for the movement of poor-quality water, pollutants, and contaminants. Because monitoring wells are often purposely located in areas affected by pollutants and contaminants, they pose an especially significant threat to ground water quality if they are not properly constructed, altered, maintained, and destroyed.

The California Legislature amended the California Water Code in 1986 specifically to include requirements for monitoring well standards. Monitoring wells were previously assumed by the Department to be covered by the collective term "well" in the law.

History of Monitoring Wells

Monitoring wells were first used mainly for water level measurement. These wells were often referred to as piezometers in reference to the "piezometric surface" of ground water. In recent years, the term "piezometric surface" is often replaced by "potentiometric surface." However, the term "piezometer" is still sometimes used for monitoring wells installed only for water level measurement.

Many water level monitoring wells constructed in the past were relatively large in diameter in comparison to today's monitoring wells. Wells up to 10-inches in diameter were often constructed to accommodate various means of water level measurement, including floats for mechanically-operated, continuous water level recorders. Many inactive water wells that could accommodate mechanical water level recording equipment were used as monitoring wells.

Modern electronic water level measuring and recording devices now allow for small-diameter water-level monitoring wells. Some continuous water-level measurement devices can be used in wells less than 2-inches in inside diameter.

The use of monitoring wells for ground water sampling for chemical analysis has increased significantly in the past two decades. The following factors have all served to increase the frequency and scope of ground water quality investigations and the number of monitoring wells constructed:

Advances in analytical and environmental chemistry;

Increased knowledge of the adverse effects of chemicals on humans;

Public awareness of ground water pollution;

The advent of federal ground water quality protection legislation in the 1970s, and,

Statutes relating to ground water quality enacted by the California Legislature.

Since the 1970s an entire industry has developed around ground water quality monitoring and monitoring well construction. Numerous private firms are involved in providing technical services for the design and implementation of ground water quality investigations. Many firms are involved in the manufacture, distribution, and marketing of materials and equipment used in constructing and operating monitoring wells.

Most monitoring wells constructed today are used to assess:

- The nature and distribution of pollutants and contaminants in ground water;
- The nature and distribution of naturally occurring chemical constituents;
- Subsurface hydrologic conditions; and,
- Hydraulic properties of strata as they relate to pollutant and contaminant movement.

Some monitoring wells are designed to be multipurpose. Monitoring wells can sometimes be used as "extraction" or "injection" wells for mitigation of pollution or contamination.

Although a significant number of monitoring wells constructed today are for detection and assessment of ground water quality impairment, many monitoring wells are constructed for evaluating ground water supply conditions by allowing ground water level measurement and/or aquifer testing. Still others are constructed for observing water levels associated with excavations and irrigated agriculture.

During 1989, approximately 20 percent of all well drilling in California was for monitoring wells, based on well driller's reports received by the Department of Water Resources. Monitoring wells have been constructed in nearly all California counties. The largest concentrations of water quality monitoring wells occur in metropolitan areas of the State. Large numbers of monitoring wells are installed for detection and assessment of leaks from underground storage tanks.

Types of Monitoring Wells

For the purpose of these standards, the term "monitoring well" is limited to wells designed to monitor subsurface water in the saturated zone, existing at or above atmospheric pressure (ground water); rather than water, water vapor, and/or gases contained in the unsaturated or vadose zone. Monitoring devices used for the unsaturated zone differ significantly from those used for the saturated (ground water) zone.

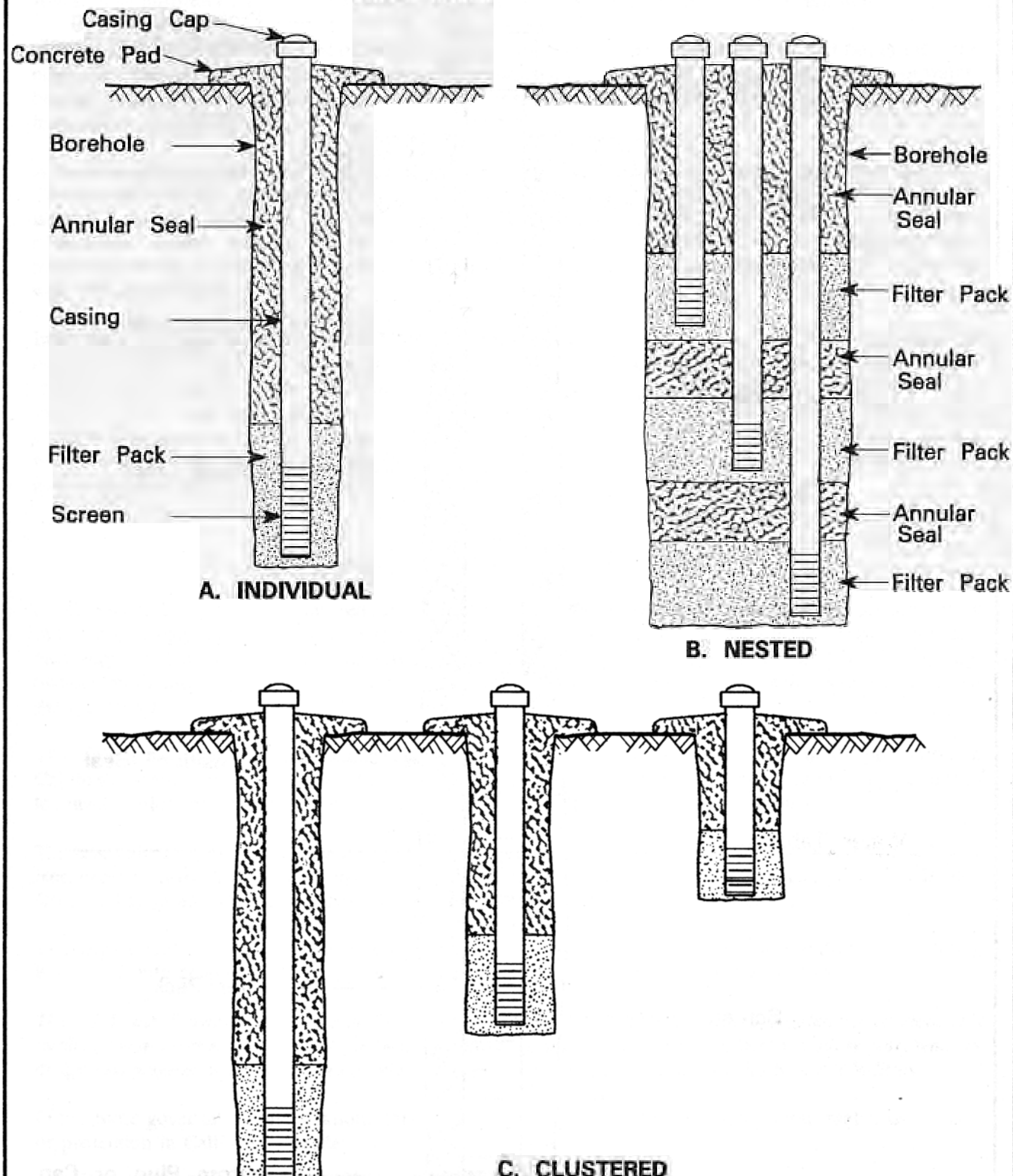
As shown in Figure 2, three basic types of monitoring wells or "installations" are:

- Individual monitoring wells;
- Nested monitoring wells; and,
- Clustered monitoring wells.

Individual monitoring wells consist of a single casing "string" within a borehole, as illustrated in Figures 2 and 3. Individual monitoring wells are installed in unique locations apart from one another. They are the most common type of monitoring well constructed in California.

Figure 2. MONITORING WELL TYPES

(NOTE: Schematic, not to scale)

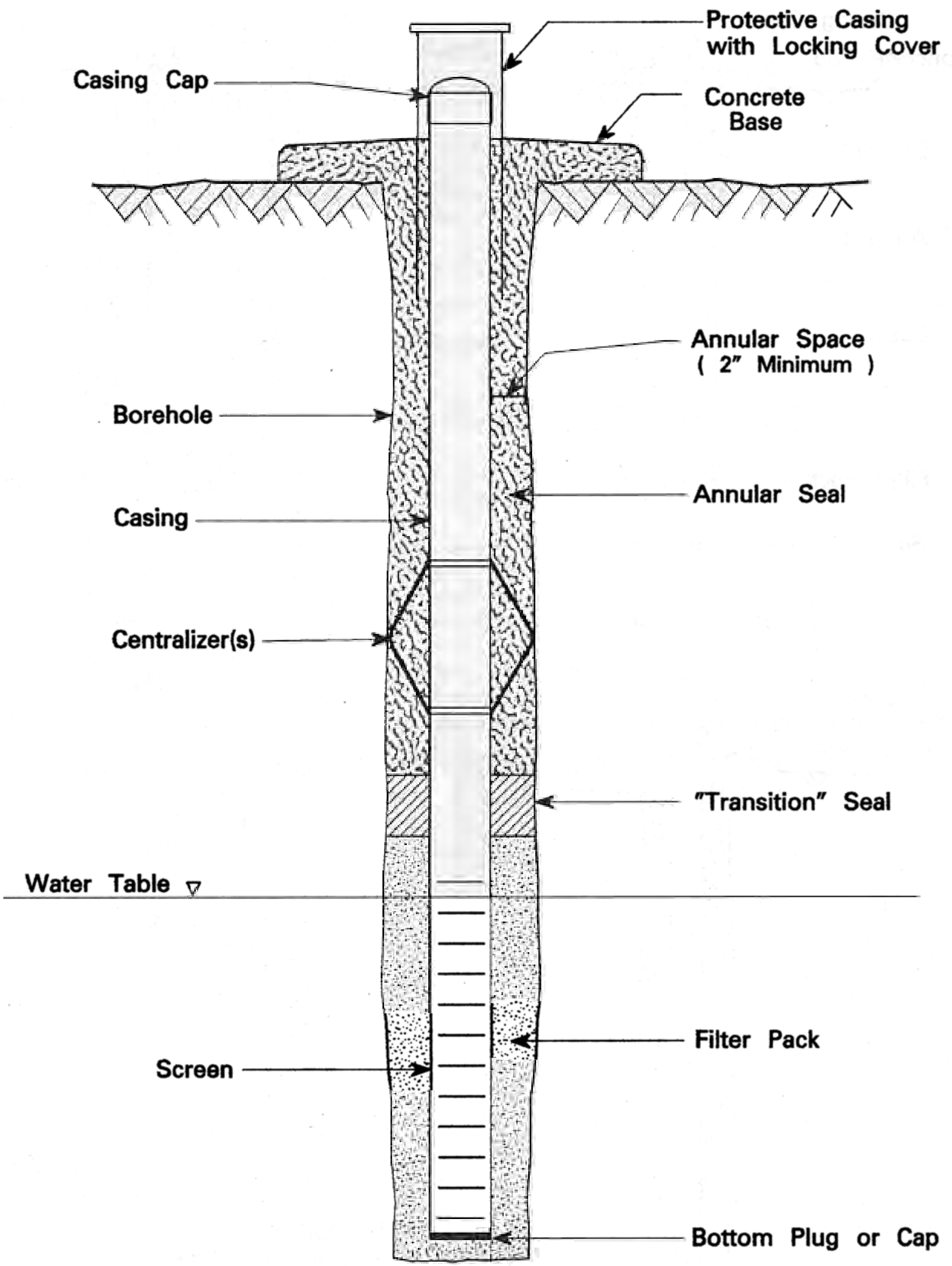


C. CLUSTERED
(Separated but close to one another)

Monitoring wells

Figure 3. CROSS SECTION OF A TYPICAL MONITORING WELL

(NOTE: Schematic, not to scale)



Nested monitoring wells consist of two or more casing strings within the same borehole. Normally the screened interval of each casing string is designed to obtain water from different aquifers or water-bearing zones. The purpose of a nested monitoring well is much the same as clustered monitoring wells.

Clustered monitoring wells consist of individual monitoring wells situated close together, but not in the same borehole. The wells within a cluster are normally constructed to obtain water from different aquifers or water-bearing zones. Clustered wells are most often used for monitoring ground water conditions at various depths in roughly the same area.

A nested monitoring well can be difficult to construct because of multiple casings within the same borehole. Care is required during construction to ensure water-bearing zones for each casing string are hydraulically isolated from one another and the annular seals are effective. Some regulatory agencies may prohibit the use of nested monitoring wells for certain contamination or pollution investigations. Normally this can be due to uncertainties about whether water-bearing strata can be isolated and whether the annular seals in a nested well are always effective.

Individual casing strings for the various types of monitoring wells discussed above, are sometimes designed to obtain water from more than one aquifer or water-bearing unit. These casing strings usually have multiple intervals of openings or screen. Such well casing strings, often referred to as "multi-level monitoring wells," can sometimes serve as a preferential pathway for the movement of poor quality water, pollutants, and contaminants from one unit to another. Some regulatory agencies prohibit the use of multi-level monitoring wells for certain pollution or contamination investigations out of concern for water quality protection and data quality requirements.

Authority and Responsibilities of Other Agencies

As discussed above, Congress enacted major legislation dealing with ground water quality protection during the 1970s. Regulatory programs initiated by federal legislation, such as the Resources Conservation and Recovery Act (RCRA) and its amendments, are administered by the U. S. Environmental Protection Agency. Some administration and enforcement activities related to federal legislation have been delegated to California State agencies.

The California Legislature enacted legislation expanding efforts for ground water quality protection in California beyond federal requirements. The Legislature assigned several State agencies various responsibilities for investigation, mitigation, and control of ground water pollution and contamination.

The lead enforcement agency for most ground water quality protection issues in California is the State Water Resources Control Board (State Board) and the nine California Regional Water Quality Control Boards (Regional Boards). The State Board oversees the activities of the nine regional boards.

The Department of Health Services or, under some circumstances, the U. S. Environmental Protection Agency, is the lead enforcement agency for ground water quality issues related to hazardous wastes.

The EPA, the Department of Health Services, and the State Board have adopted regulations or standards establishing monitoring requirements for "waste facilities". These regulations or standards include requirements for design and performance of monitoring wells that are often more stringent than standards in this bulletin.

Other State government organizations concerned or directly involved with ground water quality assessment or protection in California include:

- Department of Conservation, Division of Oil and Gas,

Monitoring wells

Department of Food and Agriculture,

- Integrated Waste Management Board, and,

Department of Water Resources.

California cities, counties, and local water agencies are also involved with ground water quality assessment and protection.

The Division of Oil and Gas has authority and responsibility for geothermal wells and other special wells constructed in the State's Geothermal Resources Areas (pursuant to Chapter 4, Division 3, California Public Resources Code). Shallow wells drilled for geothermal observation are subject to regulations and standards established by DOG.

After July 17, 1991 the California Environmental Protection Agency will oversee the activities of the State Water Resources Control Board and the Integrated Waste Management Board. Some of the environmental protection activities of the Department of Health Services and the Department of Food and Agriculture will also come under the California Environmental Protection Agency.

Scope, Organization, and Limitations of Standards

Certain standards that apply to water wells also apply to monitoring wells. Therefore the Monitoring Well Standards refer frequently to the Water Well Standards. Standards that apply only to monitoring wells, or that require emphasis, are discussed in detail in the Monitoring Well Standards. The Monitoring Well Standards are arranged in a format similar to the Water Well Standards.

These standards are not intended as a complete manual for monitoring well construction, alteration, maintenance, and destruction. These standards serve only as minimum statewide guidelines towards ensuring that monitoring wells do not constitute a significant pathway for the movement of poor quality water, pollutants, or contaminants. These standards provide no assurance that a monitoring well will perform a desired function. In most cases ground water monitoring practices and monitoring well performance, or functional requirements, fall under the purview of the various agencies mentioned earlier. ***Ultimate responsibility for the design and performance of a monitoring well rests with the well owner and/or the owner's contractor, and/or technical representative(s).***

STANDARDS

Part I. General

Section 1. Definitions[1].

A. Monitoring Well. The term "monitoring well" is defined in Section 13712 of the California Water Code as:

> "...any artificial excavation by any method for the purpose of monitoring fluctuations in groundwater levels, quality of underground waters, or the concentration of contaminants in underground waters."

B. Exploration Hole (or Boring). An uncased temporary excavation whose purpose is the immediate determination of hydrologic conditions at a site.

C. Enforcing Agency. An agency designated by duly authorized local, regional, or State government to administer and enforce laws or ordinances pertaining to the construction, alteration, maintenance, and destruction of monitoring wells.

Section 2. Application to Well Type.

These standards apply to all types of monitoring wells, except as prescribed in Sections 3, 4, and 5, below. Before a change in use of a well is made, any standards for the new use must be complied with.

Section 3. Exemptions for Unusual Conditions.

Under certain circumstances the enforcing agency may waive compliance with these standards and prescribe alternate requirements. These standards may be waived where they are impractical or ineffective because of unusual conditions or would result in an unsatisfactory condition or well function. In waiving any of these standards the enforcing agency shall, if at all possible, require measures be implemented to provide the same or greater level of water-quality protection that would otherwise be provided by these standards.

Section 4. Exclusions.

Most standards in Part II, "Monitoring Well Construction," page 41, do not apply to "exploration holes." However, provisions of Section 7, "Reports," below and Part III, "Destruction of Monitoring Wells," page 50, do apply directly to exploration holes.

Exploration holes for determining suitability of on-site domestic sewage disposal that are less than 10 feet in depth are exempt from the reporting and destruction requirements of these standards.

Large volume excavations for determining the suitability of on-site domestic sewage disposal, such as backhoe trenches, that exceed ten feet in depth are exempt from the requirements of Part III of these standards. However, such excavations shall be backfilled with the excavated material or other suitable fill material and the backfill compacted in lifts to attain at least 90 percent relative compaction in order to restore physical conditions in the excavation as much as possible. If a layer or layers of material that serve to impede the

[1] Selected technical terms are defined in Appendix A, page 77.

movement of poor-quality water, pollutants and contaminants are penetrated by the excavation, they shall be reestablished to the degree possible to provide protection for underground waters, unless otherwise approved by the enforcing agency. In some cases it may be necessary to backfill all or a portion of the excavation with sealing material meeting these standards to reestablish natural barriers to the movement of poor-quality water, pollutants, and contaminants.

Section 5. Special Standards.

The enforcing agency may prescribe measures more stringent than standards presented here, where needed to protect public safety or protect water quality.

Section 6. Responsible Parties.

Pursuant to Section 13750.5 (Division 7, Chapter 10, Article 3) of the California Water Code; construction, alteration, and destruction of monitoring wells shall be performed by contractors licensed in accordance with the California Contractors' License Law (Division 3, Chapter 9, California Business and Professions Code), except where exempted by law. Construction, alteration, or destruction of monitoring wells to monitor hazardous waste facilities, other waste facilities, or underground storage tanks, shall be performed under the supervision of a California Registered Professional Engineer, California Registered Geologist, or California Certified Engineering Geologist, where specified by law.

Section 7. Reports.

Monitoring well construction, alteration, and destruction reports shall be completed on forms provided by the California Department of Water Resources. Other types of forms may be used for submission to the Department with the prior approval of the Department. The completed forms shall be submitted to the Department in accordance with relevant provisions of Sections 13750 through 13754 (Division 7, Chapter 10, Article 3) of the California Water Code. Information concerning completion and submission of well construction, alteration, and destruction reports is contained in *Guide to the Preparation of the Water Well Drillers Report*, Department of Water Resources, October 1977, or its latest revision.

Part II. Monitoring Well Construction

Section 8. Well Location With Respect to Pollutants and Contaminants, and Structures.

Monitoring wells are usually constructed to observe conditions at defined or required locations. Monitoring well locations are usually selected on the basis of known or expected hydrologic, geologic, and water quality conditions and the location of pollutant or contaminant sources. Monitoring wells frequently need to be located close to or within areas of pollution or contamination.

A. Separation. Monitoring wells shall be located an adequate distance from known or potential sources of pollution and contamination, including those listed in Section 8 of the Water Well Standards, unless regulatory or legitimate data requirements necessitate they be located closer.

B. Flooding and Drainage. Monitoring wells should be located in areas protected from flooding, if possible. Provisions for locating monitoring wells in areas of flooding and drainage are contained in Section 8 of the Water Well Standards.

C. Accessibility. All monitoring wells shall be located an adequate distance from buildings and other structures to allow access for well maintenance, modification, repair, and destruction, unless otherwise approved by the enforcing agency.

D. Disposal of Wastes When Drilling in Contaminated or Polluted Areas. Drill cuttings and wastewater from monitoring wells or exploration holes in areas of known or suspected contamination or pollution shall be disposed of in accordance with all applicable federal, State, and local requirements. The enforcing agency should be contacted to determine requirements for the proper disposal of cuttings and wastewater.

Section 9. Sealing the Upper Annular Space.

The space between the monitoring well casing and the wall of the well boring, usually referred to as the "annular space," shall be effectively sealed to prevent it from being a preferential pathway for the movement of poor quality water, pollutants, and contaminants. Since monitoring wells are often constructed to obtain water from discrete intervals, a secondary purpose of the annular seal can be to isolate the well intake section or screen to one water-bearing unit. The annular seal can also serve to protect the structural integrity of the well casing and to protect the casing from chemical attack and corrosion. Because monitoring wells are often located close to, or within areas affected by pollutants and contaminants, an effective annular seal is often critical for the protection of ground water quality.

General discussion of sealing methods and requirements for monitoring wells is contained in Section 9, Section 13, and Appendix B, of the Water Well Standards. Special requirements for monitoring wells include the following:

A. Minimum Depth of Annular Seal.

1. Water quality monitoring wells and monitoring wells constructed in areas of known or suspected pollution or contamination. The annular space shall be sealed from the top of the filter pack or monitoring zone to ground surface, unless otherwise approved by the enforcing agency. The top of the filter pack or monitoring zone shall not extend into another water-bearing unit above the single water-bearing unit being monitored unless otherwise approved by the enforcing agency. The filter pack or monitoring zone shall not extend into any confining layers that overlie or underlie the unit to be moni-

tored, unless otherwise approved by the enforcing agency. The annular surface seal shall be no less than 20 feet in length.

Seal lengths less than 20 feet are permissible only if shallow zones will be monitored and approval has been obtained from the enforcing agency. If possible, special protection shall be provided where a reduced-length seal is used, as described in Section 8 of the Water Well Standards.

2. Other Monitoring Wells. The upper annular seal shall extend from ground surface to a minimum depth of 20 feet. An annular seal less than 20 feet in length is permissible if provisions in Item 1, above, are followed.

3. Sealing Off Strata. Additional annular sealing material shall be placed below the minimum depth of the upper annular seal, as is needed, to prevent the movement of poor-quality water, pollutants, and contaminants through the well to zones of good-quality water. Requirements for sealing off zones are in Section 13 of the Water Well Standards.

4. Shallow Water Level Observation Wells. Water level observation wells less than 15 feet in total depth that are used to assess root zone drainage in agricultural areas are exempt from an annular surface seal requirement, unless otherwise required by the enforcing agency.

5. Areas of Freezing. The top of the annular seal may be below ground surface in areas where freezing is likely. Such areas include those listed in Section 9 of the Water Well Standards. The top of the annular seal shall not be more than 4 feet below ground surface. The remainder of the space above the seal may be made an integral part of a vault, in accordance with Section 10, Subsection E, page 45, below.

6. Vaults. At the approval of the enforcing agency, the top of the annular seal and well casing can be below ground surface where traffic or other conditions require. In no case shall the top of the annular seal be more than 4 feet below ground surface.

   The top of the annular seal shall contact a suitable, watertight, structurally-sound subsurface vault, or equivalent feature, that encloses the top of the well casing in accordance with Section 10, Subsection E, page 45, below. The vault shall extend from the top of the annular seal to at least ground surface.

B. Sealing Conditions.

1. Temporary Conductor Casing. If "temporary" conductor casing is used during drilling, it shall be removed during the placement of the casing and annular seal materials, as described in Section 9 of the Water Well Standards. If the temporary conductor casing "cannot" be removed, as defined in Section 9 of the Water Well Standards, sealing material shall be placed between the conductor casing and borehole wall, and between the well casing and conductor casing, in accordance with methods described in Section 9 of the Water Well Standards. Sealing material shall extend to at least the depths specified in Subsection A of this section.

2. Permanent Conductor Casing. If a permanent conductor casing is to be installed, the monitoring well borehole diameter shall be at least 4 inches greater than the outside diameter of the conductor casing. The inner diameter of the permanent conductor

casing shall in turn be at least 4 inches greater than the outside diameter of the well casing.

Sealing material shall be placed between the permanent conductor casing and the borehole wall, and the conductor casing and the well casing. The sealing material shall extend to at least the depths specified in Subsection A of this section.

C. Radial Thickness of Seal. A minimum of two inches of sealing material shall be maintained between all casings and the borehole wall, within the interval to be sealed, except as noted in Section 9 of the Water Well Standards. At least two inches of sealing material shall also be maintained between all "casings" in a borehole, within the interval to be sealed unless otherwise approved by the enforcing agency. Additional space shall be provided, where needed, to allow casings to be properly centralized and spaced and allow the use of a tremie pipe during well construction (if required), especially for deeper wells.

D. Sealing Material. Sealing material shall consist of neat cement, sand-cement, or bentonite clay. Cement-based sealing material shall be used opposite fractured rock, unless otherwise approved by the enforcing agency. Concrete shall be used only with the approval of the enforcing agency.

Sealing material shall be selected based on required structural, handling, and sealing properties, and the chemical environment into which it is placed. Used drilling mud or cuttings from drilling shall not be used for any part of sealing material.

1. Water. Water used for sealing mixtures should generally be of drinking water quality, shall be compatible with the type of sealing material used, shall be free of petroleum and petroleum products, and shall be free of suspended matter. Good-quality water is necessary to ensure that sealing materials achieve proper consistency for placement and achieve adequate structural and sealing properties.

   Nonpotable water can sometimes be used for preparing cement-based sealing materials. In no case shall the concentration of chloride in water used in cement-based sealing material exceed 2,000 milligrams per liter. Sulfate shall not exceed 1,500 mg/l.

   Water used for sealing material shall be chemically analyzed if unknown. Only drinking-quality water of known composition should be used for preparing sealing mixtures for monitoring wells to be used for sensitive water-quality determinations.

2. Cement-Based Sealing Materials. Discussion and standards for cement-based sealing materials are contained in Section 9 of the Water Well Standards. Special considerations that apply to monitoring wells are:

   a. Additives. Care should be exercised in the use of special additives for cement-based sealing materials, such as those used for modifying cement setting times. Some additives could interfere with sensitive water quality determinations.

   b. Cooling Water. In the case of water quality monitoring wells, care should be exercised in the use of circulating cooling water to protect plastic casing from heat build-up during setting of cement-based sealing materials. Water introduced and/or circulated in a well for cooling could interfere with water quality determinations.

3. Bentonite-Based Sealing Materials. Discussion and standards for bentonite-based sealing materials are contained in Section 9 of the Water Well Standards.

E. Transition Seal. A bentonite-based transition seal, up to 5 feet in length, is often placed in the annular space to separate filter pack and cement-based sealing materials. The transition seal can prevent cement-based sealing materials from infiltrating the filter pack. A short interval of fine-grain sand, usually less than 2 feet in length, is often placed between the filter pack and the bentonite transition seal to prevent bentonite from entering the filter pack. Also, fine sand is sometimes used in place of bentonite as the transition seal material.

Fine-grain forms of bentonite, such as granules and powder, are usually employed for a transition seal if a transition seal is to be placed above the water level in a well boring. Coarse forms of bentonite, such as pellets and chips, are often used where a bentonite transition seal is to be placed below the water level.

Transition seals should be installed by using a tremie pipe or equivalent. However, some forms of bentonite may tend to bridge or clog in a tremie pipe.

Bentonite can be placed in the well annulus in dry form or as slurry for transition seals. Water should be added to the bentonite transition seal prior to the placement of cement-based sealing materials where the bentonite is dry in the borehole. Care should be exercised during the addition of water to the borehole to prevent displacing the bentonite.

Water should be added to bentonite at a ratio of about 1 gallon for every 2 pounds of bentonite to allow for proper hydration. Water added to bentonite for hydration or to make a slurry shall be of suitable quality and free of pollutants and contaminants.

Sufficient time should be allowed for bentonite transition seals to properly hydrate before cement-based sealing materials are placed. Normally, 1/2 to 1 hour is required for hydration to occur. Actual time of hydration is a function of site conditions.

The top of the transition seal shall be sounded to ensure that no bridging occurred during placement.

F. Placement of Annular Seal Material. All loose cuttings and other obstructions shall be removed from the annular space before sealing materials are placed. Sealing may be accomplished by using pressure grouting techniques, a tremie pipe, or equivalent. Sealing materials shall be installed as soon as possible during well construction operations. Sealing materials shall not be installed by "free-fall" from the surface unless the interval to be sealed is dry and less than 30 feet deep.

Casing spacers shall be used within the interval(s) to be sealed to separate individual well casing strings from one another in a borehole of a nested monitoring well. The spacers shall be placed at intervals along the casing to ensure a minimum separation of 2 inches between individual casing strings. Spacers shall be constructed of corrosion-resistant metal, plastic, or other non-degradable material. Wood shall not be used as spacer material.

Any metallic component of a spacer used with metallic casing shall consist of the same material as the casing. Metallic spacer components shall meet the same metallurgical specifications and standards as the casing to reduce the potential for galvanic corrosion of the casing.

The spacing of casing spacers is normally dictated by casing materials used, the orientation and straightness of the borehole, and the method used to install the casing. Spacers shall not be more than 12 inches in length and shall not be placed closer than 10 feet apart along a casing string within the interval to be sealed, unless otherwise approved by the enforcing agency.

Casing spacers shall be designed to allow the proper passage and distribution of sealing material around casing(s) within the interval(s) to be sealed.

Additional discussion and standards for placement of the annular seal are contained in Section 9, Section 13, and Appendix B of the Water Well Standards.

Section 10. Surface Construction Features.

Surface construction features of a monitoring well shall serve to prevent physical damage to the well; prevent entrance of surface water, pollutants, and contaminants; and prevent unauthorized access.

A. Locking Cover. The top of a monitoring well shall be protected by a locking cover or equivalent level of protection to prevent unauthorized access.

B. Casing Cap. The top of a monitoring well casing shall be fitted with a cap or "sanitary seal" to prevent surface water, pollutants, or contaminants from entering the well bore. Openings or passages for water level measurement, venting, pump power cables, discharge tubing, and other access shall be protected against entry of surface water, pollutants, and contaminants.

C. Flooding. The top of the well casing shall terminate above ground surface and known levels of flooding, except where site conditions, such as vehicular traffic, will not allow.

D. Bases. Unless otherwise approved by the enforcing agency, a concrete base or pad shall be constructed around the top of a monitoring well casing at ground surface and contact the annular seal, unless the top of the casing is below ground surface as provided by Subsection E, below. The base shall be at least 4 inches thick and shall slope to drain away from the well casing. The base shall extend at least two feet laterally in all directions from the outside of the well boring, unless otherwise approved by the enforcing agency.

   The base shall be free of cracks, voids, and other significant defects likely to prevent water tightness. Contacts between the base and the annular seal, and the base and the well casing must be water tight and must not cause the failure of the well casing or annular seal.

   Where cement-based annular sealing material is used, the concrete base shall be poured before the annular seal has set, unless otherwise approved by the enforcing agency.

E. Vaults. At the approval of the enforcing agency, the top of the well casing may be below ground surface because of traffic or other critical considerations. A structurally-sound watertight vault, or equivalent feature, shall be installed to house the top of a monitoring well that is below ground surface. The vault shall extend from the top of the annular seal to at least ground surface. In no case shall the top of the annular seal be more than 4 feet below ground surface.

   The vault shall contact the annular seal in a manner to form a watertight and structurally sound connection. Contacts between the vault and the annular seal, and the vault and the well casing, if any, shall not fail or cause the failure of the well casing or annular seal.

   Where cement-based annular seal materials are used, the vault shall be set into or contact the annular seal material before it sets, unless otherwise approved by the enforcing agency. If bentonite-based sealing material is used for the annular seal, the vault should be set into the bentonite before it is fully hydrated.

Cement-based sealing material shall be placed between the outer walls of the vault and the excavation into which it is placed to form a proper, structurally sound foundation for the vault, and to seal the space between the vault and excavation. Bentonite-based sealing material may be used between the vault and excavation at the approval of the enforcing agency.

Sealing material surrounding a vault shall extend from the top of the annular seal to ground surface, unless precluded in areas of freezing. If cement-based sealing material is used for both the annular seal and the space between the excavation and vault, the sealing material shall be placed in a "continuous pour." In other words, cement-based sealing material shall be placed between the vault and excavation and contact the cement-based annular seal before the annular seal has set.

The vault cover or lid shall be watertight but shall allow the venting of gases, unless otherwise approved by the enforcing agency. The lid shall be fitted with a security device to prevent unauthorized access. The lid shall be clearly and permanently marked "MONITORING WELL." The vault and its lid shall be strong enough to support vehicular traffic where such traffic might occur.

The top of the vault shall be set at or above grade so drainage is away from the vault. The top of the well casing contained within the vault shall be covered in accordance with requirements under Subsections A and B, above, so that water, contaminants, or pollutants that may enter the vault will not enter the well casing.

F. Protection From Vehicles. Protective steel posts, or the equivalent, shall be installed around a monitoring well casing where it is terminated above ground surface in areas of vehicular traffic. The posts shall be easily seen and shall protect the well from vehicular impact.

Additional requirements for surface construction features are in Section 10 of the Water Well Standards.

Section 11. Filter Pack.

Monitoring well filter pack material shall consist of nonreactive, smooth, rounded, spherical, granular material of highly uniform size and known composition. Filter pack material shall not degrade or consolidate after placement. The grain-size of the filter pack shall be matched to the slot size of the well screen so that any movement of filter pack material into the well will be limited to prevent significant voids in the filter pack that could ultimately destabilize the annular seal.

Filter pack material shall be obtained from clean sources. Filter pack material should be washed and properly packaged for handling, delivery, and storage, if used in monitoring wells constructed for sensitive water quality determinations.

Care should be exercised in the storage of filter pack materials at a drilling site to ensure the material does not come into contact with pollutants or contaminants. Care should also be exercised to prevent the introduction of foreign substances, such as clay or vegetative matter, that might interfere with the placement and function of the filter pack.

Filter pack material shall be placed in the well boring by use of a tremie pipe or equivalent. The depth of the top of the filter pack shall be carefully checked and the volume of emplaced filter pack material verified to determine that filter pack materials have not bridged during installation.

Section 12. Casing.

The term "casing" in its broadest sense includes all tubular materials that are permanent features of a well. Screens, collars, risers, liners, and blank casing in monitoring wells maintain the well bore and provide a passage for ground water level measurement and/or sample-collection devices.

Protective casing serves to prevent accidental or intentional damage to a well. Protective casing normally consists of heavy gauge metallic pipe placed over the portion of the well casing that extends above ground surface.

Conductor casing usually functions as a temporary means of shoring the walls of a well boring to allow drilling and the placement of well construction materials. If used, temporary conductor casing is usually driven into place during drilling and is withdrawn at the same time filter pack and annular seal materials are installed around the well casing. Sometimes conductor casing is left in place and is made a permanent feature of the completed well structure. Requirements for sealing permanent conductor casing in place are contained in Section 9.

For the purpose of these standards, the term "casing" applies to screens, collars, risers, and blank casing, and other specialized products used to maintain the well bore. General discussion and standards for casing materials are contained in Section 12 of the Water Well Standards. Special considerations that apply to monitoring well casing are described below:

A. Casing Material.

1. Chemical Compatibility. Special consideration shall be given to the selection of casing materials for monitoring wells installed in environments that are chemically "hostile". The selected casing shall resist chemical attack and corrosion.

   Special consideration should be given to the selection of casing materials for wells to be used for sensitive water-quality determinations. Chemical interaction between casing materials and pollutants, contaminants, ground water, filter pack material, and geologic materials could bias ground-water quality determinations.

2. Used Casing. Used casing may be acceptable in certain cases, at the approval of the enforcing agency.

3. Plastic and Steel Casing. Plastic and steel well casing materials are commonly used for monitoring wells. The principal plastics used for water-quality monitoring wells are thermoplastics and fluorocarbon resins.

   Standards for **thermoplastic** well casing are in Section 12 of the Water Well Standards. The principal thermoplastic material used for water quality monitoring wells is polyvinyl chloride (PVC).

   Fluorocarbon casing materials include fluorinated ethylene propylene (FEP) and polytetrafluoroethylene (PTFE). Fluorocarbon resin casing materials are generally considered immune to chemical attack. Fluorocarbon casing materials shall meet the following specifications, including the latest revisions thereof:

   a. ASTM D3296, *Standard Specification for FEP-Fluorocarbon Tube.*

   b. ASTM D3295, *Standard Specifications for PTFE Tubing.*

Stainless steel is the most common form of metallic casing used in monitoring wells constructed for sensitive water quality determinations. Stainless steel casing shall meet the provisions of ASTM A312, *Standard Specification for Seamless and Welded Austenitic Stainless Pipe*, and shall meet general requirements for tubular steel products in Section 12 of the Water Well Standards.

B. Multiple Screens. Monitoring well casing strings shall not have openings in multiple water-bearing units (multi-level monitoring wells), if poor-quality water, pollutants, or contaminants in units penetrated by the well could pass through the openings and move to other units penetrated by the well and degrade ground water quality, unless otherwise approved by the enforcing agency.

C. Bottom Plugs. The bottom of a monitoring well casing shall be plugged or capped to prevent sediment or rock from entering the well.

D. Casing Installation. Discussion and standards for the installation of casing materials are in Section 12 of the Water Well Standards. Special considerations for monitoring wells are:

1. Cleanliness. Casing, couplings, centralizers, and other components of well casing shall be clean and free of pollutants and contaminants at the time of installation.

2. Joining Plastic Casing. Depending on the type of material and its fabrication, plastic casing shall be joined (threaded or otherwise coupled) in a manner that ensures its water tightness. Organic solvent welding cements or glues should not be used for joining plastic casing if glues or cement compounds could interfere with water-quality determinations.

3. Impact. Casing shall not be subjected to significant impact during installation that may damage or weaken the casing.

Section 13. Well Development.

Monitoring well development, redevelopment, and reconditioning shall be performed with care so as to prevent damage to the well and any strata surrounding the well that serve to restrict the movement of poor-quality water, pollutants, and contaminants. Development, redevelopment, and reconditioning operations shall be performed with special care where a well has been constructed in an area of known or suspected pollution or contamination. Such special care is necessary to prevent the spread of pollutants and contaminants in the environment and to protect public health and safety.

Water, sediment, and other waste removed from a monitoring well for "development" operations shall be disposed of in accordance with applicable federal, State, and local requirements. The enforcing agency should be contacted concerning the proper disposal of waste from development operations.

Appropriate methods of well development vary with the type and use of a monitoring well. Development methods that may be acceptable under certain circumstances include:

A. Mechanical Surging. Plungers, bailers, surge blocks, and other surging devices shall incorporate safety valves or vents to prevent excessive pressure differentials that could damage casing or screen.

B. Overpumping and Pump Surging. Overpumping and surging may not be suitable for development of wells producing large amounts of sediment because of the potential for clogging or jamming of pumps.

C. Air Development. Some air development methods are not acceptable for monitoring wells to be used for sensitive water-quality determinations.

D. Water Jetting. Water used in jetting operations shall be free of pollutants and contaminants. Water-jetting methods are not always acceptable for monitoring wells used for sensitive water-quality determinations.

E. Chemical Development. Extreme care shall be exercised in the use of chemicals for monitoring well development. It is often unacceptable to use chemicals for developing monitoring wells to be used for water-quality determinations. Chemicals introduced for development shall be completely removed from the well, filter pack, and water-bearing strata accessed by the well immediately after development operations are completed.

The various methods described above are sometimes used in combination.

Section 14. Rehabilitation and Repair of Monitoring Wells.

For the purpose of these standards, "well rehabilitation" includes the treatment of a well to recover loss in yield caused by incrustation or clogging of the screen, filter pack, and/or water-bearing strata adjoining the well. Well rehabilitation methods that may, in certain cases, be acceptable for monitoring wells include mechanical surging, backwashing or surging by alternately starting or stopping a pump, surging with air, water jetting, sonic cleaning, chemical treatment, or combinations of these.

Rehabilitation methods shall be performed with care to prevent damage to the well and any barriers that serve to restrict the movement of poor-quality water, pollutants, or contaminants. Chemicals used for rehabilitation shall be completely removed from the well, filter pack, and water-bearing strata accessed by the well immediately after rehabilitation operations are completed. Chemicals, water, and other waste shall be disposed of in accordance with applicable federal, State, and local requirements. The enforcing agency should be contacted regarding the proper disposal of waste from rehabilitation operations.

Rehabilitation methods should be compatible with the use of the monitoring well. Special care should be given to the selection of rehabilitation methods for water-quality monitoring wells.

Materials used for repairing well casing shall meet the requirements of Section 12 of these standards.

Section 15. Temporary Cover.

The well or borehole opening and any associated excavations shall be covered at the surface to ensure public safety and to prevent the entry of foreign material, water, contaminants, and pollutants whenever work is interrupted by such events as overnight shutdown, poor weather, and required waiting periods to allow setting of sealing materials and the performance of tests. The cover shall be held in place or weighted down in such a manner that it cannot be removed except by equipment or tools.

Part III. Destruction of Monitoring Wells

Section 16. Purpose of Destruction.

A monitoring well or exploration hole subject to these requirements that is no longer useful, permanently inactive or "abandoned" must be properly destroyed to:

(1) Ensure the quality of ground water is protected, and,

(2) Eliminate a possible physical hazard to humans and animals.

Section 17. Definition of "Abandoned" Monitoring Well.

A monitoring well is considered "abandoned" or permanently inactive if it has not been used for one year, unless the owner demonstrates intention to use the well again. In some cases regulatory agencies may require that an inactive monitoring well be maintained for future use.

In accordance with Section 24400 of the California Health and Safety Code, the monitoring well owner shall properly maintain an inactive well, as evidence of intention for future use, in such a way that the following requirements are met:

"(1) The well shall not allow impairment of the quality of water within the well and ground water encountered by the well.

(2) The top of the well or well casing shall be provided with a cover, that is secured by a lock or by other means to prevent its removal without the use of equipment or tools, to prevent unauthorized access, to prevent a safety hazard to humans and animals, and to prevent illegal disposal of wastes in the well. The cover shall be watertight where the top of the well casing or other surface openings to the well are below ground level, such as in a vault or below known levels of flooding. The cover shall be watertight if the well is inactive for more than five consecutive years. A pump motor, angle drive, or other surface feature of a well, when in compliance with the above provisions, shall suffice as a cover.

(3) The well shall be marked so as to be easily visible and located, and labeled so as to be easily identified as a well.

(4) The area surrounding the well shall be kept clear of brush, debris, and waste materials."

Section 18. General Requirements.

All permanently inactive or "abandoned" monitoring wells and exploration holes subject to these requirements shall be properly destroyed. The purposes of destruction are to eliminate the well structure and borehole as a possible means for the preferential migration of poor-quality water, pollutants, and contaminants; and, to prevent a possible hazard to humans and animals.

Section 19. Requirements for Destroying Monitoring Wells and Exploration Holes.

General requirements for destroying monitoring wells and exploration holes are contained in Section 23 of the Water Well Standards. Special considerations for monitoring wells and exploration holes are as follows.

A. Monitoring Wells. Monitoring wells shall be destroyed in accordance with the following requirements and Section 23 of the Water Well Standards, **irrespective of their original date of construction.**

1. Preliminary Work. A monitoring well shall be investigated before it is destroyed to determine its condition and details of its construction. The well shall be sounded immediately before it is destroyed to make sure no obstructions exist that will interfere with filling and sealing.

   The well shall be cleaned before destruction as needed so that all undesirable materials, including obstructions to filling and sealing, debris, oil from oil-lubricated pumps, or pollutants and contaminants that could interfere with well destruction, are removed for disposal.

   The enforcing agency shall be notified as soon as possible if pollutants or contaminants are known or suspected to be present in a well to be destroyed. Well destruction operations may then proceed only at the approval of the enforcing agency. The enforcing agency should be contacted to determine requirements for proper disposal of all materials removed from a well to be destroyed.

2. Sealing Conditions. The following minimum requirements shall be followed when various conditions are encountered.

   a. The monitoring well casing, and any other significant voids within the well, shall, at a minimum, be completely filled with sealing material, if the following conditions exist:

      - **The monitoring well is located in an area of known or potential pollution or contamination, and,**
      - **The well was constructed and maintained in accordance with these standards.**

      Sealing material may have to be placed under pressure to ensure that the monitoring well is properly filled and sealed.

   b. A monitoring well shall be destroyed by removing all material within the original borehole, including the well casing, filter pack, and annular seal; and the created hole completely filled with appropriate sealing material, if the following conditions exist:

      - **The well is located in an area of known or potential pollution or contamination, and,**
      - **The well's annular seal, casing, screen, filter pack, or other components were not constructed or maintained according to these standards so that well destruction by merely filling the well casing with sealing material, as in "a" above, would not prevent potential water-quality degradation from**

Monitoring wells

the movement of poor-quality water, pollutants, or contaminants through the destroyed well structure.

Material to be extracted from the original borehole shall be removed by means of drilling, including overdrilling, if necessary. The enforcing agency should be contacted to determine requirements for proper disposal of removed materials.

Casing, filter pack, and annular seal materials may be left in place during sealing operations, if the enforcing agency agrees they cannot or should not be removed. In such a case, appropriate sealing material shall be placed in the well casing, filter pack, and all other significant voids within the entire well boring. Casing left in place may require perforation or puncturing to allow proper placement of sealing materials. Sealing material may have to be applied under pressure to ensure its proper distribution.

c. **Monitoring wells shall, at a minimum, be destroyed in accordance with the requirements of Section 23 of the Water Well Standards if located in an area free of any known or potential contamination or pollution.**

B. Exploratory Borings. Exploratory borings shall be completely filled with appropriate sealing material from bottom to top, if located in areas of known or suspected contamination or pollution. Borings located outside such areas shall, at a minimum, be filled with sealing material from ground surface to the minimum depths specified in Section 23 of the Water Well Standards. Additional sealing material shall be placed below the minimum surface seal where needed to prevent the interchange of poor-quality water, pollutants, or contaminants between strata penetrated by the boring.

Appropriate fill or sealing material shall be placed below and between intervals containing sealing material. Sealing material is often economical to use as fill material.

The boring shall be inspected immediately prior to filling and sealing operations. All obstructions and pollutants and contaminants that could interfere with filling and sealing operations shall be removed prior to filling and sealing. The enforcing agency shall be notified as soon as possible if pollutants or contaminants are known or suspected to be in a boring to be destroyed. Well destruction operations may then proceed only at the approval of the enforcing agency. The enforcing agency should be contacted to determine requirements for proper disposal of removed materials.

C. Placement of Material. The placement of sealing material for monitoring wells and exploratory borings is generally described in Section 23 and Appendix B of the Water Well Standards. The following additional requirements shall be observed when placing sealing material for monitoring well or exploratory boring destruction.

1. Placement Method. The well or exploratory boring shall be filled with appropriate sealing, and fill material where allowed, using a tremie pipe or equivalent, proceeding upward from the bottom of the well or boring.

   Sealing material shall be placed by methods (such as the use of a tremie pipe or equivalent) that prevent freefall, bridging, and dilution of sealing materials, and/or prevent separation of aggregate from sealants. Sealing material may be placed by freefall only where the interval to be sealed is dry and no more than 30 feet in depth. Fill material shall be placed by methods that prevent bridging and voids.

2. Timing of Placement. Sealing material shall be placed in one continuous operation (or "pour") from the bottom to the top of the well or boring, unless conditions in the well or boring dictate that sealing operations be conducted in a staged manner, and prior approval is obtained from the enforcing agency.

3. Ground Water Flow. Special care shall be used to restrict the flow of ground water into a well or boring while placing sealing and fill material, if subsurface pressure producing the flow is significant.

4. Sealing Pressure. Pressure required for the placement of cement-based sealing materials shall be maintained long enough for cement-based sealing materials to properly set.

5. Verification. It shall be verified that the volume of sealing and fill material placed during destruction operations equals or exceeds the volume to be filled and sealed. This is to help determine whether the well or boring has been properly destroyed and that no jamming or bridging of the fill or sealing material has occurred.

D. Sealing and Fill Materials. Materials used for sealing exploratory borings and monitoring wells shall have low permeabilities so that the volume of water and possible pollutants and contaminants passing through them will be of minimal consequence. Sealing material shall be compatible with the chemical environment into which it is placed, and shall have mechanical properties consistent with present and future site uses.

Suitable sealing materials include neat cement, sand-cement, and bentonite, all of which are described in Section 9 of these standards. Bentonite shall not be used as a sealing material opposite zones of fractured rock, unless otherwise approved by the enforcing agency. Drilling mud or drill cuttings are not acceptable as any part of sealing material for well destruction. Concrete may be used as a sealing material at the approval of the enforcing agency.

Fill material, if any, shall meet the requirements of Section 23 of the Water Well Standards. Fill material shall be free of pollutants and contaminants and shall not be subject to decomposition or consolidation after placement. Drilling mud or cuttings are not acceptable as any part of fill material.

E. Additional Requirements for Monitoring Wells and Exploratory Borings in Urban Areas. The following additional requirements shall be met for destroying monitoring wells and exploratory borings in urban areas, unless otherwise approved by the enforcing agency:

1. The upper surface of the sealing material shall end at a depth of 5 feet below ground surface; and,

2. If the well casing was not extracted during destruction and sealing operations, a hole shall be excavated around the well casing to a depth of 5 feet below ground surface after sealing operations have been completed and the sealing material has adequately set and cured. The exposed well casing shall then be removed by cutting the casing at the bottom of the excavation. The excavation shall be backfilled with clean, native soil or other suitable material.

F. Temporary Cover. The well or borehole opening and any associated excavations shall be covered at the surface to ensure public safety and to prevent the entry of foreign material, water, pollutants, and contaminants; whenever work is interrupted by such events as overnight shutdown, poor weather, and required waiting periods to allow setting of sealing materials and the performance of tests. The cover shall be held in place or weighted down in such a manner that it cannot be removed, except by equipment or tools.

CATHODIC PROTECTION WELLS

Cathodic protection wells

CATHODIC PROTECTION WELL STANDARDS

INTRODUCTION

Most wells in California are constructed to extract ground water, inject water, or monitor ground water conditions. Other, less common types of wells include cathodic protection wells. Cathodic protection wells, sometimes called "deep groundbeds," house devices to minimize electrolytic corrosion of metallic pipelines, tanks, and other facilities in contact with the ground.

Electrolytic Corrosion

For the purpose of these standards, electrolytic corrosion is defined as the deterioration of metallic objects by electrochemical reaction with the environment. The electrolytic corrosion process is illustrated in Figure 4 for a metallic pipeline in a soil-water environment. This process gradually weakens the pipeline and can cause its failure.

In Figure 4, an electric potential is induced on the surface of the pipeline as a result of variations in the concentrations of salts in the soil and water surrounding the pipeline. This potential results in an electric current in the soil-water electrolyte. Current flows from an "anode area" on the pipeline to a "cathode area" on the pipeline. Metal is removed from the anode area by the current.

Cathodic Protection

"Cathodic protection" is a term used for certain measures taken to prevent or minimize electrolytic corrosion of metallic equipment and structures. Cathodic protection devices redirect current to flow from a "sacrificial" anode to the soil-water electrolyte, instead of from an anode area on a pipeline or other metallic structure to be protected. The protective anode's role is to corrode in place of the metallic object it is designed to protect, as shown in Figure 5. The protected facility is made to be a permanent cathode by use of cathodic protection devices. Thus, the facility is said to be "cathodically protected."

Protective or sacrificial anodes can be placed close to ground surface or at significant depth. Anodes have been placed at shallow depths in horizontal and vertical arrays for many years. Shallow arrays are often not well suited for metropolitan areas because of land requirements, or suited for areas where electrical interference may be high.

Deep vertical anode installations, usually referred to as "cathodic protection wells," were first developed and used during the 1940s. They were developed in response to the constraints of shallow anode arrays.

Cathodic Protection Wells

Cathodic protection wells are widely installed to protect metallic objects in contact with the ground from electrolytic corrosion. Such objects include petroleum, natural gas, and water pipelines, and related storage facilities; power lines; telephone cables; and switchyards. Cathodic protection wells are sometimes used to control electrolytic corrosion in large water wells.

Figure 4. ELECTROLYTIC CORROSION OF A BURIED PIPELINE

(NOTE: Schematic, not to scale)

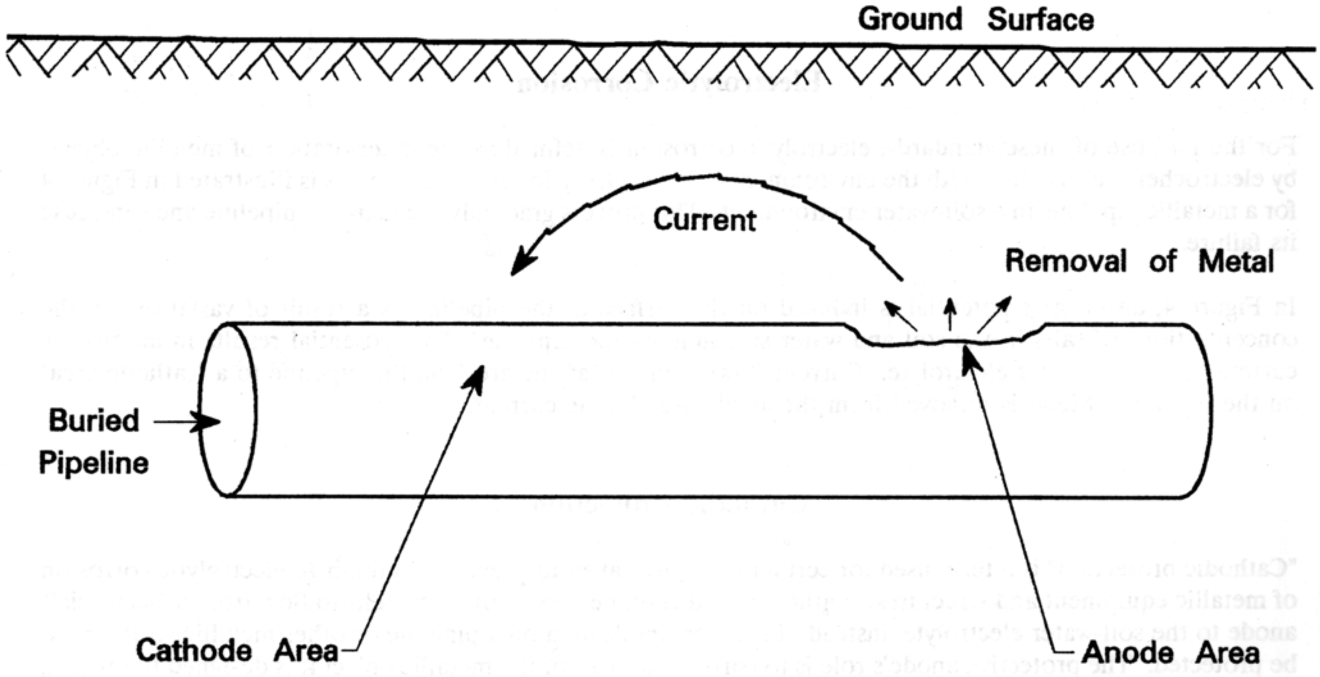
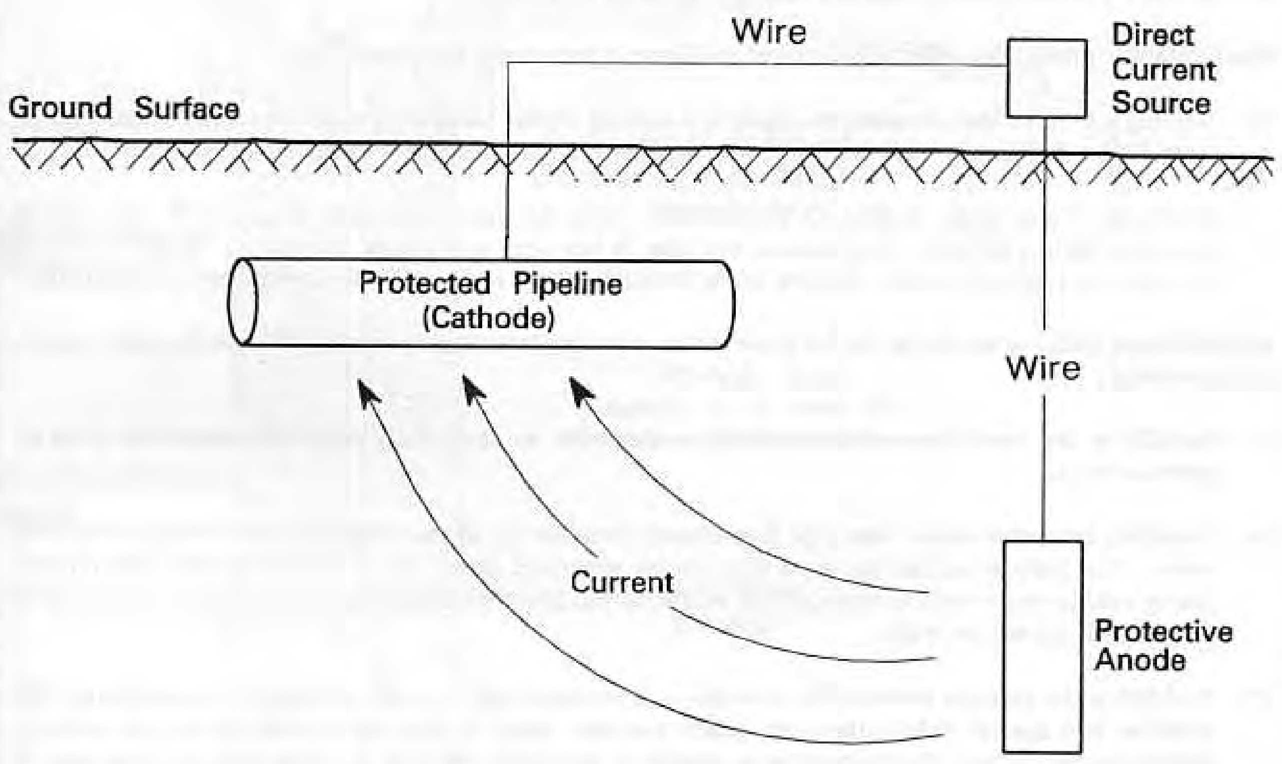


Figure 5. CATHODIC PROTECTION OF A BURIED PIPILINE

(NOTE: Schematic, not to scale)



Cathodic protection wells

Many cathodic protection wells have been constructed to protect pipelines that transport natural gas or other "hazardous" materials. The Natural Gas Pipeline Safety Act, Public Law 90-481 adopted by Congress in August 1968, provides requirements for cathodic protection of certain pipelines.

Most cathodic protection wells in California are located in areas where underground pipelines or "conveyance" systems are numerous and must be protected. These areas include:

- South coastal region from San Diego to Santa Barbara,
- Oil-producing areas of the southern San Joaquin Valley and the Central Coast, and,
- San Francisco Bay Area.

Few cathodic protection wells exist in California north of Sacramento.

Many cathodic protection wells, as illustrated in Figure 6, have been constructed by:

(1) **Drilling a 6- to 12-inch diameter borehole to a desired depth.** Cathodic protection wells normally range from 100 to 500 feet in total depth. A few wells have been constructed to depths of 800 feet.

California Water Code Section 13711 defines a "cathodic protection well" as an anode installation exceeding 50 feet in depth. Installations less than 50 feet deep are "legally" considered "shallow anodes," not cathodic protection wells. Shallow anode installations are not specifically covered by these standards.

(2) **Placing a string of anodes in the borehole within a designated interval, usually referred to as the "anode interval."**

(3) **Backfilling the anode interval around the anodes with an electrically conductive material, such as granular coke.**

(4) **Installing a small-diameter vent pipe that extends from the top of the anode interval to land surface, or above.** The purpose of the vent pipe is to release generated gases. Medium to large-diameter pipe or casing used in water wells to maintain the well bore and house pumping equipment is not normally used for cathodic protection wells.

(5) **Backfilling the annulus between the vent pipe and borehole wall with an electrically non-conductive fill material to a specific height above the anode interval.** Such fill material usually consists of uniform, small-diameter gravel. Its purpose is to provide a permeable medium for migration of gases and to stabilize the walls of the borehole.

In the past this material was sometimes used to fill the annulus between the vent pipe and the borehole wall from the top of the anode interval to land surface. These standards require specific interval(s) of the upper annular space of a cathodic protection well be filled with sealing materials instead of gravel, to protect ground water quality.

(6) **Sealing the annulus between the vent pipe and the borehole wall, from the top of the non-conductive annular fill to land surface, with sealing material.**

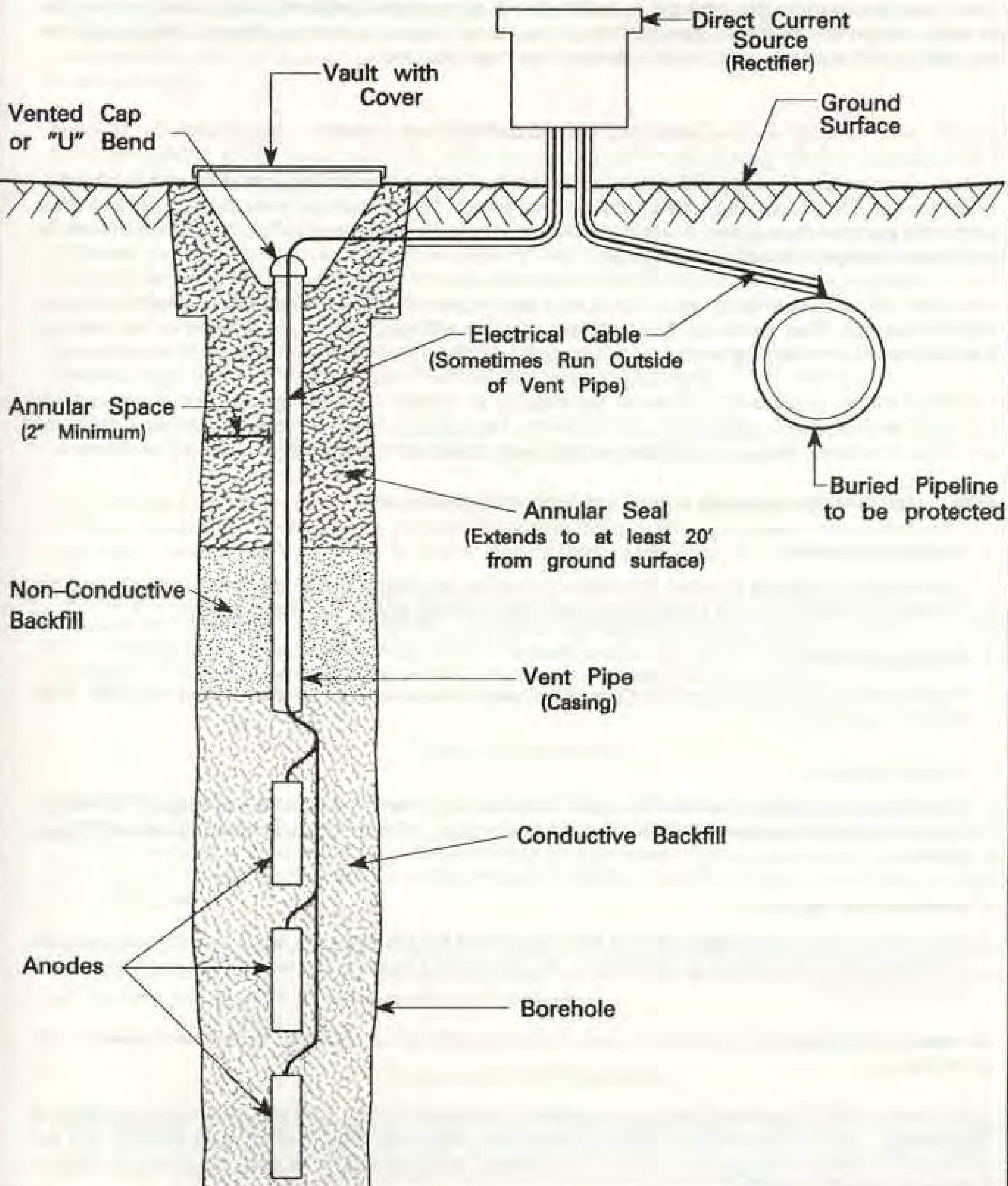
(7) **Installing a permanent cover over the well at ground surface.**

(8) **Connecting the anode leads to the facility to be protected, possibly through an electrical current source.**

Individual designs of cathodic protection wells vary.

Figure 6. CROSS SECTION OF A TYPICAL CATHODIC PROTECTION WELL

(NOTE: Schematic, not to scale)



The protective anodes of a cathodic protection well usually corrode away with time. Thus a cathodic protection well's anodes determine the well's useful life. Anodes are usually designed to last 15 to 20 years.

There has been an increasing tendency to construct cathodic protection wells with large diameter vent pipe or casing so that anodes can be replaced through the casing. Anode replacement through casing eliminates the need to drill replacement wells when anodes have been expended.

Corrosion Coordinating Committees

Serious electrical interference problems can occur where cathodic protection networks criss-cross one another or are too close to one another. Also, stray currents produced from electrical transmission lines and other equipment can sometimes interfere with the operation of cathodic protection systems. Interference problems are usually most pronounced in urban areas.

Corrosion control coordinating organizations have been formed in areas of California to overcome system interferences and other problems. Most organizations are affiliated with or are chapters of the National Association of Corrosion Engineers.

Corrosion control organizations represent the majority of utilities and other groups that install cathodic protection devices, including cathodic protection wells. Organization members coordinate the installation and operation of cathodic protection facilities with the goal of minimizing problems of electrical interference.

Four organizations that deal with Central and Southern California, are:

- **Southern California**

  The Southern California Cathodic Protection Committee is a formal committee covering all of Southern California south of San Luis Obispo, Kern, and Inyo counties, except San Diego County.

- **San Diego County**

  The San Diego County Underground Corrosion Control Committee is an informal organization that deals with the San Diego area.

- **Central California**

  The Central California Cathodic Protection Committee is a formal committee covering all of Central California plus Sacramento Valley counties, and western Sierra Nevada mountain counties south of Plumas County.

- **San Francisco Bay Area**

  The activities of the two committees that formerly covered the San Francisco Bay Area have been assumed by the San Francisco Section of the National Association of Corrosion Engineers. The committees were disbanded in 1985.

No coordinating organizations function in coastal counties north of San Francisco or in the northeastern part of the State.

Unfortunately, not all who install and operate cathodic protection facilities work with a corrosion coordinating organization. Those not associated with an organization are usually individuals or local agencies that are sometimes unaware of the existence of other installations. Non-coordinated facilities can seriously interfere with one another electrically.

Need for Cathodic Protection Well Standards

Cathodic protection wells, along with other types of wells, can allow ground water quality degradation to occur. Improperly constructed or destroyed cathodic protection wells can constitute a preferential pathway for the movement of poor-quality water, pollutants, and contaminants. Cathodic protection wells constructed with gravel backfill to land surface are particularly conducive to the movement of poor-quality water, pollutants, or contaminants.

Water and electrolytes are sometimes introduced into cathodic protection wells through vent pipes, or gravel fill in the annulus, to keep wells functional where natural electrolytes are lacking. Such a practice could be considered "waste disposal" and may be illegal if poor-quality water is used.

Permanently inactive cathodic protection wells pose a threat for the movement of poor-quality water, pollutants, and contaminants, and should be properly destroyed. Permanently inactive cathodic protection wells are a threat to ground water quality because they become dilapidated with time, are sometimes forgotten, and are sometimes used for waste disposal.

Many cathodic protection wells have small diameter vent pipes that prevent entry by persons and most animals. However, large vent pipe sizes can pose a serious safety threat if left open at land surface.

History of Cathodic Protection Well Standards

The California Legislature enacted legislation in 1949 directing the California Department of Water Resources to develop recommended water-quality protection standards for the construction and destruction of wells. The Legislature amended the Water Code in 1968 to require standards for cathodic protection wells.

Cathodic protection well standards for California were first published in 1973 as DWR Bulletin 74-1, *Cathodic Protection Well Standards: State of California*. Standards presented here replace those contained in Bulletin 74-1. Additional discussion on the history of well standards is contained in the "Introduction" section of this supplement (Bulletin 74-90) and Bulletin 74-81, *Water Well Standards: State of California*.

Scope of Standards

The following are recommended minimum standards for construction, alteration, maintenance, and destruction of cathodic protection wells in California. They only serve as minimum guidelines toward ensuring cathodic protection wells do not constitute a significant pathway for movement of poor-quality water, pollutants, and contaminants. These standards do not ensure a cathodic protection well will perform its corrosion protection function adequately.

The functional requirements of cathodic protection wells may conflict with the application of certain standards for the protection of water quality. Consequently, some compromise has been made between well function and resource protection in the development of these standards.

Organization of Standards

These standards are arranged in a format similar to the Water Well Standards. Since many of the standards that apply to water wells also apply to cathodic protection wells, many references are made in these standards to the Water Well Standards. Standards that apply only to cathodic protection wells or that require emphasis for cathodic protection wells, are discussed in detail in these standards.

STANDARDS

Part I. General

Section 1. Definitions[1].

A. Cathodic Protection Well. A cathodic protection well is defined in Section 13711 of the California Water Code as:

> "...any artificial excavation in excess of 50 feet constructed by any method for the purpose of installing equipment or facilities for the protection electrically of metallic equipment in contact with the ground, commonly referred to as cathodic protection."

B. Enforcing Agency. An agency designated by duly authorized local, regional, or State government to administer and enforce laws or ordinances pertaining to the construction, alteration, maintenance, and destruction of cathodic protection wells.

C. Casing. All vent pipe, anode access tubing, electrical cable conduit, and other tubular materials that pass through the interval to be sealed.

D. Conductor Casing. A tubular retaining structure temporarily or permanently installed in the upper portion of the well boring between the wall of the well boring and the inner well casing. Conductor casing is often installed to keep the borehole open during drilling if caving conditions are expected. Despite its title, conductor casing does not normally serve an "electrical" function for cathodic protection wells.

Section 2. Exemptions Due to Unusual Conditions.

Under certain circumstances the enforcing agency may waive compliance with these standards and prescribe alternate requirements. These standards may be waived only where they are impractical or ineffective because of unusual conditions, or would result in unsatisfactory condition or well function. In waiving any of these standards, the enforcing agency shall, if at all possible, require that measures be implemented to provide the same or greater level of water-quality protection that would otherwise be provided by these standards.

Section 3. Special Standards.

The enforcing agency may prescribe measures more stringent than standards described here, where needed to protect public safety or protect water quality.

Section 4. Responsible Parties.

Corrosion control engineers are normally responsible for the design and supervision of corrosion control facilities incorporating cathodic protection wells. Pursuant to Section 13750.5 (Division 7, Chapter 10, Article 3) of the California Water Code, construction, alteration, and destruction of cathodic protection wells shall be performed by contractors licensed in accordance with the California Contractors' License Law

[1] Technical terms are defined in Appendix A, page 77.

(Division 3, Chapter 9, California Business and Professions Code), except where exempted by law. Above-ground electrical facilities for cathodic protection wells should be installed by an appropriately licensed contractor.

Section 5. Reports.

Cathodic protection well construction, alteration, and destruction reports shall be completed on forms provided by the California Department of Water Resources. Other types of forms may be used for submission to the Department with the prior approval of the Department. The completed forms shall be submitted to the Department in accordance with relevant provisions of Sections 13750 through 13754 (Division 7, Chapter 10, Article 3) of the California Water Code. Information concerning completion and submission of well construction, alteration, and destruction reports is contained in *Guide to the Preparation of the Water Well Drillers Report*, Department of Water Resources, October, 1977, or its latest revision.

Part II. Cathodic Protection Well Construction

Section 6. Well Location With Respect to Pollutants and Contaminants, and Structures.

A. Separation. Cathodic protection wells shall be located an adequate distance from known or potential sources of pollution or contamination, where site constraints and corrosion control considerations allow. Potential sources of pollution and contamination include those listed in Section 8 of the Water Well Standards.

As specified in Section 7 below, the length of the annular seal for a cathodic protection well shall be increased if the well is located in a congested urban area, or is located within 100 feet of any potential source of pollution or contamination.

B. Flooding and Drainage. Cathodic protection wells should be located in areas protected from flooding, if possible. Wells located in areas of flooding shall be protected from flood waters and drainage, including protective measures outlined in Section 8, below.

Ground surface surrounding a cathodic protection well shall slope away from the well. Drainage from areas surrounding a cathodic protection well shall be directed away from the well.

C. Accessibility. All cathodic protection wells shall be located an adequate distance from buildings and other structures to allow access for well maintenance, modification, repair, and destruction, unless otherwise approved by the enforcing agency.

Section 7. Sealing the Upper Annular Space.

The space between the cathodic protection well casing and the wall of the well boring, often referred to as the "annular space," shall be effectively sealed to prevent it from being a preferential pathway for the movement of poor-quality water, pollutants, or contaminants. In some cases, secondary purposes of the annular seal are to stabilize the borehole wall, protect casing from degradation or corrosion, and ensure the structural integrity of the casing.

General discussion of sealing requirements and methods is contained in Section 9, Section 13, and Appendix B of the Water Well Standards. Special requirements for sealing cathodic protection wells are:

A. Minimum Depth of Annular Seal.

1. Minimum Depth. The annular space shall be filled with appropriate sealing material from ground surface to a depth of at least 20 feet below land surface. The annular space shall be sealed to a depth of at least 50 feet below land surface in congested urban areas, or where a cathodic protection well is within 100 feet of any potential source of pollution or contamination. Additional annular sealing material shall be installed to greater depths where adverse conditions exist that increase the risk of pollution or contamination of ground water.

2. Fill. Any annular space existing between the base of the annular surface seal and the top of the anode and conductive fill interval shall be filled with appropriate fill or sealing material. Fill material should consist of washed granular material such as sand, pea gravel, or sealing material. Fill material shall not be subject to decomposition or

consolidation after placement and shall be free of pollutants and contaminants. Fill material shall not contain drill cuttings or drilling mud. Sealing material is often more practical and economical to use for filling the annular space than granular material.

3. Sealing-Off Strata. Additional annular sealing material shall be placed below the minimum depth of the annular surface seal, as needed, to prevent the movement of poor-quality water, pollutants, and contaminants through the well to zones of good-quality water. Requirements for sealing off zones are in Section 10, below.

B. Sealing Conditions. Requirements for sealing the annular space under varied conditions are detailed in Section 9, Subsection B of the Water Well Standards.

C. Radial Thickness of Seal. A minimum of 2 inches of sealing material shall be maintained between all casings and the borehole wall within the interval to be sealed, except where temporary conductor casing cannot be removed as noted in Section 9 of the Water Well Standards. At least 2 inches of sealing material shall be maintained between all casings in a borehole, within the interval to be sealed unless otherwise approved by the enforcing agency. Additional space shall be provided, where needed, to allow casings to be properly centralized and spaced and allow the use of a tremie pipe during well construction (if required), especially for deeper wells.

D. Sealing Material. Sealing material shall consist of neat cement, sand-cement, concrete, or bentonite clay as discussed in Section 9 of the Water Well Standards. Cement-based sealing material shall be used opposite zones of fractured rock used. Concrete shall only be used at the approval of the enforcing agency. Drill cuttings and used drilling mud shall not be used as any part of sealing material.

E. Placement of Seal. Standards for the placement of annular seals are described in Section 9 and Appendix B of the Water Well Standards.

Section 8. Surface Construction Features.

Surface construction features of a cathodic protection well shall serve to prevent physical damage to the well; prevent the entry of surface water, pollutants, and contaminants; and prevent unauthorized access.

A. Locking Cover. The top of a cathodic protection well shall be protected by a locking cover or equivalent level of protection to prevent unauthorized access. All such covers shall allow the venting of gases.

B. Casing Cap. The top of a cathodic protection well casing shall be fitted with a watertight cap, cover, "U" bend, or equivalent device to prevent the entry of water, pollutants, and contaminants into the well bore. All such covers shall allow venting of gases from the well.

C. Flooding. The top of the well casing shall terminate above ground surface and known levels of flooding, except where site conditions, such as vehicular traffic, will not allow.

D. Bases. A concrete base or pad shall be constructed around the top of a cathodic protection well casing at ground surface and contact the annular seal, unless the top of the casing is to be below ground surface as provided by Subsection E, below. The base shall be at least 4 inches thick and shall slope to drain away from the well casing. The base shall extend at least

2 feet laterally in all directions from the outside of the well boring, unless otherwise approved by the enforcing agency.

The base shall be free of cracks, voids, and other significant defects likely to prevent water tightness. Contacts between the base and the annular seal, and the base and the well casing must be water tight and must not cause the failure of the well casing or annular seal.

Where cement-based annular sealing material is used, the concrete base shall be poured before the annular seal has set, unless otherwise approved by the enforcing agency.

E. Vaults. At the approval of the enforcing agency, the top of a cathodic protection well may be below ground surface because of traffic or other critical considerations. A watertight, structurally-sound vault, or equivalent feature, shall be installed to house the top of the well casing if it terminates below ground surface.

The vault shall extend from the top of the annular seal to at least ground surface. In no case shall the top of the annular seal be more than 4 feet below ground surface.

The vault shall contact the annular seal in a manner to form a watertight and structurally-sound connection. Contacts between the vault and the annular seal, and the vault and the well casing (if any), shall not fail, or cause the failure of the well casing or annular seal.

Where cement-based annular sealing materials are used, the vault shall be set into or contact the annular sealing material before it sets, unless otherwise approved by the enforcing agency. If bentonite-based sealing material is used for the annular seal, the vault shall be set into the bentonite before it is fully hydrated.

Cement-based sealing material shall be placed between the outer walls of the vault and the excavation into which it is placed to form a proper, structurally sound foundation for the vault, and to seal the space between the vault and excavation.

Sealing material surrounding the vault shall extend from the top of the annular seal to ground surface, unless precluded in areas of freezing. If cement-based sealing material is used for both the annular seal and the space between the excavation and vault, the sealing material shall be emplaced in a "continuous pour." In other words, cement-based sealing material shall be placed between the vault and excavation and contact a cement-based annular seal before the annular seal has set.

The vault cover or lid shall be watertight but shall allow the venting of gases. The lid shall be fitted with a security device to prevent unauthorized access and shall be clearly and permanently labeled "CATHODIC PROTECTION WELL." The vault and its lid shall be strong enough to support vehicular traffic where such traffic might occur.

The top of the vault shall be set at grade, or above, so that drainage is away from the vault. The top of the casing contained within the vault shall be capped in accordance with requirements of Subsection B, above so that water, contaminants, and pollutants that may enter the vault will not enter the well casing.

F. Protection From Vehicles. Protective steel posts, or the equivalent, shall be installed around a cathodic protection well casing where it is terminated above ground surface in areas of vehicular traffic. The posts shall be easily seen and shall protect the well from vehicular impact.

Additional requirements for surface construction features are contained in Section 10 of the Water Well Standards.

Section 9. Casing.

Vent pipe, anode access tubing, and any other tubular materials that pass through the interval to be filled and sealed are all considered casing for the purpose of these standards. Materials used for cathodic protection well casing generally shall meet the requirements for casing materials and their installation in Section 12 of the Water Well Standards. Variance from the standards shall be at the approval of the enforcing agency. It is recommended that practices prescribed by the National Association of Corrosion Engineers also be followed in the design and installation of gas vents and electrical conduit.

Cathodic protection well casing should be at least 2 inches in internal diameter to facilitate eventual well destruction.

Section 10. Sealing-Off Strata.

If a cathodic protection well penetrates a stratum or strata below the minimum required annular surface seal depth specified in Section 7, above and that stratum contains poor-quality water, pollutants, or contaminants that could mix with and degrade water contained in other strata penetrated by the well, additional annular sealing material shall be placed below the minimum required annular surface seal to prevent mixing and water-quality degradation.

The following minimum requirements shall be observed for isolating zones containing poor-quality water, pollutants, or contaminants for various cases:

Case 1. Upper Stratum. If a stratum containing poor-quality water, pollutants, or contaminants lies above a stratum to be protected, annular seal material shall extend from the top of the stratum containing the poor-quality water, pollutants, or contaminants down to at least 10 feet into the confining layer separating the two strata, or through the entire thickness of the confining layer, whichever is least.

Case 2. Lower Stratum. If a stratum containing poor-quality water, pollutants, or contaminants lies below a stratum to be protected, the annular space opposite the stratum to be protected shall be sealed along its full length. The seal shall extend at least 10 feet into the confining layer separating the two strata, or through the entire thickness of the confining layer, whichever is least.

Case 3. Multiple Strata.

a. **Where two or more strata containing poor-quality water, pollutants, or contaminants are adjacent to one another and overlie a stratum to be protected,** the annular space opposite the strata containing poor-quality water, pollutants, or contaminants and opposite all interbedded confining layers shall be sealed. The annular seal shall extend at least 10 feet down into, or completely through, whichever is least, the confining layer separating the strata containing poor-quality water, pollutants, or contaminants and the underlying stratum to be protected.

b. **Where two or more strata containing poor-quality water, pollutants, or contaminants underlie a stratum to be protected,** the annular space opposite the stratum to be protected shall be sealed. The seal shall continue down at least 10 feet into, or completely through, whichever is least, the confining layer separating the stratum to be protected and the underlying strata containing poor-quality water, pollutants or contaminants.

c. **Where two strata containing poor-quality water, pollutants, or contaminants are separated by a stratum to be protected,** the annular space opposite the stratum to be protected, the confining strata underlying and overlying the stratum to be protected, and the upper stratum containing poor-quality water, pollutants, or contaminants shall be sealed off.

The supplementary seals described in the cases above shall be extended up to and contact the base of the required minimum annular surface seal described in Section 7 above, if they are otherwise required to be within 10 feet of the surface seal. Sealing the entire annulus above the anode interval will often economically fulfill the conditions outlined above.

Requirements for sealing materials and their placement are described in Section 7, above.

Section 11. Repair of Cathodic Protection Wells.

Materials used for repairing cathodic protection well casing shall meet the requirements of Section 9, above.

Section 12. Temporary Cover.

The well or borehole opening and any associated excavations shall be covered at the surface to prevent the entry of foreign material, water, pollutants, and contaminants, and to ensure public safety whenever work is interrupted by such events as overnight shutdown, poor weather and required waiting periods to allow setting of sealing materials and the performance of tests. The cover shall be held in place or weighted down in such a manner that it cannot be removed except by equipment or tools.

Part III. Destruction of Cathodic Protection Wells

Section 13. Purpose of Destruction.

A cathodic protection well that is no longer useful, permanently inactive or "abandoned" must be properly destroyed to:

(1) Ensure the quality of ground water is protected, and,

(2) Eliminate a possible physical hazard to humans and animals.

Section 14. Definition of "Abandoned" Cathodic Protection Well.

A cathodic protection well is considered "abandoned" or permanently inactive when its anodes are exhausted and cannot, or will not, be replaced. A cathodic protection well is also considered "abandoned" or permanently inactive if it has not been used for one year, unless the owner demonstrates intention to use it again. To provide evidence of intention for future use of a well, the well owner, in accordance with Section 24400 of the Health and Safety Code, shall maintain the well in such a way that the following requirements are met:

"(1) The well shall not allow impairment of the quality of water within the well and ground water encountered by the well.

(2) The top of the well or well casing shall be provided with a cover, that is secured by a lock or by other means to prevent its removal without the use of equipment or tools, to prevent unauthorized access, to prevent a safety hazard to humans and animals, and to prevent illegal disposal of wastes in the well. The cover shall be watertight where the top of the well casing or other surface openings to the well are below ground level, such as in a vault or below known levels of flooding. The cover shall be watertight if the well is inactive for more than five consecutive years. A pump motor, angle drive, or other surface feature of a well, when in compliance with the above provisions, shall suffice as a cover.

(3) The well shall be marked so as to be easily visible and located, and labeled so as to be easily identified as a well.

(4) The area surrounding the well shall be kept clear of brush, debris, and waste materials."

Section 15. General Requirements.

All permanently inactive or "abandoned" cathodic protection wells shall be properly destroyed. The purpose of destruction is to prevent a possible safety hazard to humans and animals and to eliminate the well structure as a possible means for the preferential migration of poor-quality water, pollutants, and contaminants.

Section 16. Requirements for Destroying Cathodic Protection Wells.

General requirements for well destruction are contained in Section 23 of the Water Well Standards. Special considerations for cathodic protection wells are as follows:

A. <u>Preliminary Work</u>. A cathodic protection well shall be investigated before it is destroyed to determine its condition, details of its construction and whether conditions exist that will interfere with filling and sealing.

The well shall be sounded immediately before it is destroyed to make sure that no obstructions exist that will interfere with filling and sealing. The well shall be cleaned before destruction, as needed, to ensure that all undesirable materials, including obstructions to filling and sealing, debris, and pollutants and contaminants that could interfere with well destruction are removed for disposal. The enforcing agency shall be notified as soon as possible if pollutants and contaminants are known or suspected to be in a well to be destroyed. Well destruction operations may then proceed only at the approval of the enforcing agency. The enforcing agency should be contacted to determine requirements for proper disposal of materials removed from a well to be destroyed.

B. Filling and Sealing Conditions. The following minimum requirements shall be followed when various conditions are encountered.

1. Wells that only penetrate unconsolidated material and a single "zone" of ground water. At a minimum, the upper 20 feet of the well casing and the annulus between the well casing and borehole wall (if not already sealed) shall be completely sealed with suitable material. Sealing material shall extend to a minimum depth of 50 feet below land surface if the well to be destroyed is located in an urban area, or is within 100 feet of any potential source of pollution or contamination. Additional sealing material may be needed if adverse conditions exist. The remainder of the well below the minimum surface seal shall be filled with suitable granular fill material, such as clean sand or pea gravel, or with sealing material.

2. Wells that penetrate several water-bearing strata. The upper portion of the well casing and annular space shall be filled with sealing material as described in Item 1, above. Strata encountered below the surface seal that contain poor-quality water, pollutants, or contaminants that could mix with and degrade water in other strata penetrated by the well, shall be effectively isolated by sealing the well bore and annulus within intervals specified in Section 10, above. The remainder of the well shall be filled with suitable granular fill or sealing material.

3. Wells penetrating fractured rock. Sealing material shall be installed as outlined in Items 1 and 2, above. Cement-based sealing material shall be used opposite fractured rock. The remainder of the well shall be filled with fill or sealing material, as appropriate.

4. Wells in nonfractured consolidated strata. Sealing material shall be installed as outlined in Items 1 and 2, above. The remainder of the well shall be filled with fill or sealing material, as appropriate.

5. Wells penetrating water-bearing zones or aquifers of special significance. The enforcing agency may require that specific water-bearing zones be sealed off for well destruction.

C. Placement of Material. The placement of sealing materials for cathodic protection well destruction is generally described in Section 23 and Appendix B of the Water Well Standards. The following additional requirements shall be observed in destroying cathodic protection wells.

Casing, cables, anodes, granular backfill, conductive backfill, and sealing material shall be removed as needed, by redrilling, if necessary, to the point needed to allow proper placement of sealing materials within required sealing intervals. Removal of some or all well materials will likely be required for cathodic protection wells that were not constructed in accordance with these standards, or standards adopted by the Southern California Cathodic Protection Committee in December 1969.

Casing that cannot be removed shall be adequately perforated or punctured at specific intervals to allow pressure injection of sealing materials into granular backfill and all other voids that require sealing.

The following requirements shall be observed in placing fill and sealing material in cathodic protection wells to be destroyed.

1. Placement Method. The well shall be filled and sealed with appropriate material upward from the bottom of the well using a tremie pipe or equivalent.

   Sealing material shall be placed by methods (such as by the use of a tremie pipe or equivalent) that prevent freefall, bridging, or dilution of the sealing materials, or separation of aggregates from sealants. Sealing materials shall not be installed by freefall unless the interval to be sealed is dry and no deeper than 30 feet below ground surface.

2. Timing of Placement. Sealing material shall be placed in one continuous operation (or "pour") from the bottom to the top of the well unless conditions in the well dictate that sealing operations be conducted in a staged manner and prior approval is obtained from the enforcing agency.

3. Ground Water Flow. Special care shall be used to restrict the flow of ground water into a well while fill and sealing material is being placed, if subsurface pressure causing the flow of water is significant.

4. Sealing Pressure. Pressure required for placement of cement-based sealing material shall be maintained long enough for the cement-based sealing material to set.

5. Verification. Verification shall be made that the volume of sealing and fill material placed in a well during destruction operations equals or exceeds the volume to be filled and sealed. This is to help determine that the well has been properly destroyed and that no jamming or bridging of the fill or sealing material has occurred.

D. Sealing Materials. Materials used for sealing cathodic protection wells for destruction shall have low permeabilities so that the volume of water and possible pollutants and contaminants passing through them will be of minimal consequence. Sealing material shall be compatible with the chemical environment into which it is placed and shall have mechanical properties compatible with present and future site uses.

Suitable sealing materials include neat cement, sand-cement, concrete, and bentonite, as described in Section 9 of the Water Well Standards. Sealing materials used for isolating zones of fractured rock shall be cement-based, as described in Subsection B, above. Drilling mud or drill cuttings shall not be used as any part of a sealing material for well destruction. Concrete may be used as a sealing material at the approval of the enforcing agency.

E. Fill Material. Many fill materials are suitable for destruction of cathodic protection wells. These include clean, washed sand or gravel or sealing material. Fill material shall be free of pollutants and contaminants and shall not be subject to decomposition or consolidation after placement. Fill material shall not contain drilling mud or cuttings.

F. <u>Additional Requirements for Destruction of Cathodic Protection Wells in Urban Areas</u>. The following additional requirements shall be met at each well site in urban areas, unless otherwise approved by the enforcing agency:

(1) The upper surface of the sealing material shall end at a depth of 5 feet below ground surface, and,

(2) If the casing was not extracted during destruction and sealing operations, a hole shall be excavated around the well casing to a depth of 5 feet below ground surface after sealing operations have been completed and sealing materials have adequately set and cured. The exposed well casing shall then be removed by cutting the casing at the bottom of the excavation. The excavation shall then be backfilled with clean, native soil or other suitable material.

G. <u>Temporary Cover</u>. The well borehole and any associated excavations shall be covered at the surface to prevent the entry of foreign material, water, pollutants, and contaminants and to ensure public safety whenever work on the well is interrupted by such events as overnight shutdown, poor weather, and required waiting periods to allow setting of sealing materials and performance of tests. The cover shall be held in place or weighted down in such a manner that it cannot be removed except by equipment or tools.

APPENDICES

APPENDIX A

Definition of Terms

Protective Anode - A metallic object designed to corrode in place of the object it is designed to protect.

Cathodic Protection[1] - A technique to prevent the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.

Cement, Portland Cement - A cement that contains oxides of calcium, aluminum, iron, and silicon made by heating a mixture of limestone and clay in a kiln and pulverizing the resultant clinker, as defined in ASTM C150. Portland cement is also considered a hydraulic cement, because it must be mixed with water to form a cement-water paste with the ability to develop strength and harden, even under water.

Centralizer - A device that assists in centering tubular materials in a borehole.

Conductance, Specific - A measure of the ability of water to conduct electric current at 77 degrees Fahrenheit. It is related to the total concentration of ions in the water.

Corrosion[1] - The deterioration of a material, usually a metal, because of a reaction with its environment.

Drilling Fluid - A fluid (liquid or gas) used in drilling operations to remove cuttings from a borehole, to clean and cool the drilling bit, to reduce friction between the drill stem and the borehole wall, and, in some cases, to prevent caving or sloughing of the borehole.

Electrolyte[1] - A chemical substance or mixture, usually liquid, containing ions that migrate in an electric field. The term electrolyte refers to the soil or liquid adjacent to, and in contact with a buried or submerged metallic structure including the moisture and other chemicals contained therein.

Interference[1] - The situation that arises when a foreign substructure is affected in any way by a direct current source.

Rectifier[1] - An electronic device that changes alternating current to direct current.

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[1] Definition from National Association of Corrosion Engineers Standard RP-01-69 or RP-05-72.

APPENDIX B

REFERENCES

Since Bulletin 74-81 was published in mid-1981 several new or revised publications have been issued that address ground water or well construction. This appendix lists publications issued or revised since 1981 and selected other publications that were reviewed during the preparation of this supplement. Publications that were used for Bulletin 74-81 that have since been revised are identified by a number in parentheses. These numbers refer to the publication's original position in the bibliography of Bulletin 74-81 (Appendix E, page 83).

Books and Pamphlets

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Laws, Rules and Regulations

A. Pertinent laws and regulations of the State of California as contained in:

- California Code of Regulations
- California Business and Professions Code
- California Health and Safety Code
- California Public Resources Code
- California Water Code

B. The State Water Resources Control Board Model Water Well Ordinance.

C. Existing ordinances of the counties of California pertaining to the construction, alteration, and destruction of wells.

D. Laws, regulations, and recommendations of the various states pertaining to the construction, alteration, or destruction of wells.

APPENDIX H

Public Outreach and Comment Letters

LSCE

GSP Workshop#1

Overview of the SGMA
October 13, 2015

The District's staff held a Sustainable Groundwater Management Act (SGMA) Workshop on October 13, 2015 at 9:00 A.M. in the Five Points Field Office. The District hosted the workshop to engage our water users, beneficial users of groundwater, stakeholders and interested parties on SGMA. The District educated beneficial users of groundwater on their groundwater rights, Westside Subbasin groundwater conditions and SGMA. Questions received at the workshop were related to the District's role in complying with SGMA.

GSP Workshop#2

Overview of the Sustainable Groundwater Management Act
March 15, 2016

The District held its annual water users' workshop on March 15, 2016 at 1:00 P.M. at the District's Five Point Field Office. During the workshop, District's staff discussed an overview of the SGMA and GSP development. The workshop specifically covered the following GSP topics Administrative Information, Basin Settings, Sustainable Management Criteria, Monitoring Network, and Project and Management Actions. Workshop attendees were given the opportunity to provide public input on the District's GSP development.

GSP Workshop#3

Overview of the GSP Development
October 31, 2016

The District's staff held the first of many Groundwater Sustainability Plan (GSP) development workshops on October 31 at 1:00 P.M. at the District's Five Points Field Office. The District hosted the workshop to engage interested parties in the District's GSP development. Staff presentation included a high-level overview of the Sustainable Groundwater Management Act, GSA responsibilities, GSP Regulations and focused the presentation on GSP content. Staff posed four questions to the attendees to provide a forum for public input. Main comment received was the GSP's key component should be surface water reliability. Furthermore, the idea of developing a groundwater allocation to optimize the aquifer characteristics of each management area and the concept of developing a groundwater credit and trading system within the same management area was discussed. In addition to the workshop public input, the District also provided comment sheets for the public to submit comments and questions.

GSP Workshop#4

Overview of the Hydrogeology in the Westside Subbasin
December 21, 2016

The District held a GSP development workshop on December 21, 2016 at the Five Points Field Office to provide interested parties the opportunity to provide public input on the District's GSP development. The GSP workshops were divided into three discussions focused on the Subbasin conditions within the western, central and eastern hydrogeologic areas of the Westside Subbasin and email notifications. Staff presented the hydrogeologic characteristics of the Westside Subbasin, potential sustainability management options by area, and provided a forum to solicit comments and ideas on GSP development. The District received comments on the management and recharge area location recommendations and recommendations on the timing of implementing GSP guidelines.

GSP Workshop#5

Overview of the Sustainable Groundwater Management Act
March 21, 2017

The District held its annual water users' workshop on March 21, 2017 at 1:00 P.M. at the Five Points Field Office. The workshop provided attendees with current 2017-2018 water supply allocations and daily precipitation rates. An overview of the SGMA, groundwater conditions and content that would be contained within the GSP was also presented. Workshop attendees were given the opportunity to provide public input on the District's GSP content development.

GSP Workshop#6

Overview of the Hydrogeology in the Westside Subbasin
June 22, 2017

The District hosted a workshop focusing on the technical side of GSP development on June 22, 2017. Meeting attendance consisted of fourteen interested parties. The discussion was focused on the water user's perspective to GSP development and groundwater management. Meeting topics were in relation to developing groundwater credit programs, treatment facilities, groundwater replenishment programs and a sustainable yield value for the entire Subbasin.

GSP Workshop#7

Overview of the Subsidence and Groundwater Credit Options
September 22, 2017

The District hosted a workshop focusing on the technical side of GSP development on September 22, 2017. The main meeting topics were subsidence and groundwater credit options which will be incorporated in the District's GSP. Michelle Sneed with the USGS provided a presentation on land subsidence which covered causes of subsidence, methodology to measure subsidence, subsidence that has occurred in the San Joaquin Valley historically and currently. Questions received from attendees were related to the location of subsidence and aquifer response on little to no pumping. Katarina Campbell, the District's SGMA program manager, gave a presentation on potential groundwater credit scenarios that the District is considering modeling and what other Subbasins in California groundwater credit programs consist of. The presentation focused on three credit transferring options, banking unused groundwater allocation and over pumping allocation potentials. Attendees requested water users to not be penalized for conservatively pumping groundwater and requested that the District not include an adjustment loss in the GSP planning.

GSP Workshop#8

Overview of DWR's Sustainable Management Criteria BMPs
December 7, 2017

The District hosted a workshop on December 7, 2017. The meeting consisted eight interested parties. The two main meeting topics were Sustainable Management Criteria Best Management Practices and GSP development. The feedback included questions on projects being pursued to optimize groundwater pumping, when groundwater credits would be available to growers and if rates will be greater on lands with higher application rates.

GSP Workshop#9

Groundwater Management Guiding Principles & GSP Conceptual Outline
February 9, 2018

The District hosted a SGMA Workshop on February 9, 2018. The meeting covered groundwater management guiding principles for the preparation, adoption and administration of the GSP. A conceptual outline was presented with Westland's' vision on the sequence of tasks for managing groundwater and completing the GSP for the Subbasin. The outline follows the order for completion to comply with SGMA while also providing the guiding principles assurance.

GSP Workshop#10

Bilingual SGMA Community Workshop
April 6, 2018

The District hosted a Bilingual SGMA Community Workshop on April 6, 2018 at the District's Five Point Field Office. Flyer were mailed to community members, noticed in the District monthly notice and posted at local churches in the Subbasin. The main meeting topic was Article 5, GSP content which included administration information, existing groundwater conditions in both the Upper and Lower Aquifer, water budget, and public input and ideas for GSP development. The responsibilities of each agency in relation to SGMA and historically and current groundwater conditions within the Subbasin. Management actions taken to achieve sustainability include public input on the GSP.

GSP Workshop#11

Modeling Results
May 3, 2018

The District hosted a GSP Workshop on May 3, 2018 at the District's Five Point Field Office. Meeting attendance consisted of fifty- four water users, interested parties and surrounding GSA representatives. The main meeting topics were the Westside Subbasin's baseline modeling results and GSP development. The presentation included the Westside Subbasin groundwater modeling results, provide a status of the GSA's GSP development and proposed enhancement strategy for the GSP content. Attendee questions were in relation to Corcoran clay depths, water allocation average, cost of supplemental water, and ASR wells.

GSP Workshop#12

Modeling Results
May 17, 2018

The District hosted a bilingual workshop in conjunction with the San Luis & Delta-Mendota Water Authority to present the Westside Subbasin modeling results on May 17, 2018 at the Mendota Branch Library. The main meeting topics were the Westside Subbasin's baseline modeling results and GSP development. The presentation included the Westside Subbasin groundwater modeling results, provide a status of the GSA's GSP development and proposed enhancement strategy for the GSP content.

GSP Workshop#13

Bilingual Sustainable Groundwater Management Act Special Board Meeting
July 16, 2018

The District hosted a GSP Workshop on July 16, 2018 at the Harris Ranch Inn & Restaurant. Meeting attendance consisted of interested parties and surrounding GSA representatives. The main meeting topics were the overview of the Westside Subbasin's Proposed Groundwater Strategies and collection of input from stakeholders in the Westside Subbasin. A presentation on groundwater management strategy ideas that could be implemented by water users, landowners, interested parties and Westlands. Such landowner measures that may increase allocation include water user-funded projects that create new supplies and other projects that include aquifer storage and recovery, conservation, and recharge projects. Stakeholder questions were in regard 5-year allocations, information on replacing old water meters, and data that is currently being used.

GSP Workshop #14

Bilingual Sustainable Groundwater Management Act Special Board Meeting
September 17th, 2018

The District hosted a GSP Workshop on September 17th, 2018 at the Harris Ranch Inn & restaurant. Meeting attendance consisted of interested parties and surrounding GSA representatives. The main meeting topics consisted of description of the Groundwater Model, presented by Will Halligan of Luhdorff & Scalmanini, and an explanation of the model input foundation and output results. The SGMA implementation timeline was included as well to report on the progress of the development of the GSP and Groundwater model. Stakeholder questions were related to climatic inputs, Tulare Lake and other coastal ranges were included in the model.

GSP Workshop #15

Forecast Scenarios and Augmentation Strategies Meeting
April 3, 2019

The District hosted a Special Board Meeting Workshop on April 3, 2019 at the District's Five Points Office. Meeting attendance consisted of interested parties and surrounding GSA representatives. The first presentations' topics consisted of the Groundwater Model forecast outputs and updates to the model that included refined delineation, updated aquifer properties and surface water deliveries in adjacent Subbasins. The baseline scenario of the Groundwater Model, as well as five (5) different water budget scenarios, were presented to the public with the projected benefits to the Westside Subbasin. The second presentation described the Groundwater Management Strategies (Strategies) in relation to allocation options and water levels in the lower aquifer. Strategies included Aquifer Storage and Recovery and three (3) different groundwater banking projects. Stakeholder questions were related to pumping allocations, undesirable results, supplemental water cost, groundwater credits, and projects involved in the Groundwater Management Strategies, all of which are currently being evaluated.

Meeting Minutes #1

SGMA Excerpt from the October 20, 2015 Board Minutes

Mr. Gutierrez gave an update to the Board regarding the Sustainable Groundwater Management Act's progress, implementation, and schedule. District staff had been coordinating with neighboring water agencies and counties to revise the Westside Subbasin boundary to be consistent with the District's jurisdictional boundary. Additionally, staff initiated work on the preparation of a groundwater model that would assist in managing the Westside Subbasin and attended various meetings.

Meeting Minutes #2

SGMA Excerpt from the November 17, 2015 Board Minutes

Mr. Gutierrez reported that District staff continues to coordinate with neighboring water agencies and counties to revise the Westside Subbasin boundary to be consistent with the District's jurisdictional boundary. The District intends to include Broadview Water District and Naval Air Station Lemoore in the Westside Subbasin. In addition to the subbasin coordination, staff initiated work on the preparation of a groundwater model that would assist in managing the Westside Subbasin.

Mr. Gutierrez also reported that under the Sustainable Groundwater Planning Grant Program Guidelines both Fresno and Kings Counties were eligible for $500,000 to assist in complying with the Sustainable Groundwater Management Act. Staff had submitted recommendations for projects to Fresno and Kings Counties to utilize the available funds.

Finally, staff anticipated that DWR would release the draft regulations for developing and implementing the Groundwater Sustainability Plan by December 2015. The regulations would likely require coordination with county service areas and communities within Westlands, NASL, Fresno and Kings counties, and neighboring water agencies.

Meeting Minutes #3

SGMA Excerpt from the December 15, 2015 Board Minutes

Mr. Gutierrez reported that District selected Luhdorff and Scalmanini Consulting Engineers to develop the baseline groundwater model. Luhdorff and Scalmanini will do the groundwater modeling which will be the basis for developing the sustainable yield for the District's aquifer. Work was scheduled to begin in February or March of 2016.

The District, in conjunction with Fresno County and Kings County, applied for DWR's Sustainable Groundwater Planning Grant Program to help fund the development of those models and for funding efforts towards installing monitoring wells between the Westside and Kings Subbasins.

Meeting Minutes #4

SGMA Excerpt from the January 19, 2016 Board Minutes

Mr. Gutierrez reported that District staff had been tracking the Department of Water Resources regulatory development for Sustainable Groundwater Management Act implementation. District staff continues to coordinate with neighboring water agencies, cities and counties to revise the Westside Subbasin boundary to be consistent with the District's jurisdictional boundary. In reviewing the existing Westside Subbasin boundary identified in DWR's Bulletin 118, the District Basin Boundary Modification Request will affect sixteen different agencies.

Mr. Gutierrez also reported that in addition to the subbasin coordination, staff initiated work on the preparation of a groundwater model that would assist in managing the Westside Subbasin. The groundwater model would simulate the current conditions of the subbasin, provide technical information to develop the Groundwater Sustainability Plan and allow staff to evaluate groundwater management options.

Mr. Gutierrez noted that the due date for the District to establish itself as the Groundwater Sustainability Agency for the Westside Subbasin was June 30, 2017. Staff anticipated that DWR would release draft regulations for developing and implementing the GSP this month. Following release of the GSP regulations, staff would seek direction from the Board regarding creation of the GSA to represent the Westside Subbasin.

Meeting Minutes #5

SGMA Excerpt from the February 16, 2016 Board Minutes

Mr. Gutierrez reported that the most significant update on the Sustainable Groundwater Management Act was submission of the Basin Boundary Modification Request to the Department of Water Resources that coincides with the District's jurisdictional boundary. Additionally, the District was still waiting for the Groundwater Sustainability Plan Regulations. After those plans are received and reviewed, a determination would need to be made regarding the District's willingness to serve as the groundwater sustainability agency.

Meeting Minutes #6

SGMA Excerpt from the March 15, 2016 Board Minutes

Mr. Gutierrez reported that the Board of Directors previously adopted Resolution 106-16, which authorized staff to submit the District's Basin Boundary Modification Request to the Department of Water Resources, and that staff submitted the request the prior week. The District's request included letters of support from the San Luis & Delta-Mendota Water Authority, Kings River Conservation District, Tulare Lake Basin Water Storage District, Pleasant Valley Water District, the San Joaquin River Exchange Contractors Water Authority and the City of Huron.

Mr. Gutierrez also reported that the Department of Water Resources released the draft regulations for development and implementation of the Groundwater Sustainability Plan on February 18, 2016. Staff was reviewing the Plan and would submit comments on April 1, 2016. In summary, the Groundwater Sustainability Plan requires that the Groundwater Sustainability Agency develop and implement a plan that ensures the Westside Subbasin, or any basin is managed sustainably. Additionally, the Agency must demonstrate within the plan that it is achieving the objectives and minimum thresholds and milestones established by the Department of Water Resources.

Staff believes that the District should serve as the Groundwater Sustainability Agency and manage the Westside Subbasin and will make this formal recommendation to the Board in July.

Meeting Minutes #7

SGMA Excerpt from the April 19, 2016 Board Minutes

Mr. Gutierrez reported that District staff continues to track the Department of Water Resources regulatory development for the Sustainable Groundwater Management Act implementation.

On March 24, 2016, the Department of Water Resources deemed the District's Basin Boundary Modification Request submission status as complete, which started the 30-day comment period. To date, the District's proposal had not received any comments. The comment period ends on April 23, 2016.

The Department of Water Resources released the draft regulations for development and implementation of the Groundwater Sustainability Plan on February 18, 2016. The District submitted comments on April 1, 2016. The District's comments promoted local control and recommended that the regulations be consistent with Sustainable Groundwater Management Act legislation.

Based on the draft Groundwater Sustainability Plan regulations, staff believed that the District should serve as the Groundwater Sustainability Agency and manage the Westside Subbasin. Staff will make this formal recommendation to the Board in July, subsequent to the release of the final Groundwater Sustainability Plan regulations.

Mr. Gutierrez reported that the District participated in applying for grant applications through Fresno and Kings counties, both of which received $500,000 to implement local programs. Fresno County's grant proposal focused on the construction and installation of monitoring wells between the Westside and Kings Subbasins. The data collected from the monitoring wells will aide in the District's groundwater modeling effort. Kings County's grant proposal focused on modeling the groundwater basin county-wide, which includes the area of Westside Subbasin in Kings County.

Meeting Minutes #8

SGMA Excerpt from the May 17, 2016 Board Minutes

Mr. Gutierrez reported that on March 24, 2016, DWR deemed the District's Basin Boundary Modification Request submission status as complete, which started the 30-day comment period. The District received one comment from the City of Mendota and staff incorporated their comment on the District's Basin Boundary Modification Request.

The Department of Water Resources released the draft regulations for development and implementation of the Groundwater Sustainability Plan on February 18, 2016 and received a total of 4,130 comment letters that addressed concerns with DWR imposing regulations inconsistent with the act, outside their authority and overly prescriptive. The California Water Commission was expected to adopt the final regulations developed by DWR by June 1, 2016.

Based on the draft Groundwater Sustainability Plan regulations, staff believe that the District should serve as the Groundwater Sustainability Agency and manage the Westside Subbasin. This item was reviewed by the Water Policy Committee and the Committee recommended that the Board serve as the Agency and submit an application to the Department of Water Resources to serve as the Agency and to carry out related actions. Two hearings will be held, one in Fresno and one in Kings County, prior to the July board meeting.

Meeting Minutes #9

SGMA Excerpt from the June 21, 2016 Board Minutes

Mr. Gutierrez reported that the District's Basin Boundary Modification Request was sent to DWR. On May 11, 2016, DWR submitted a proposed revision to the Westside Subbasin boundary, which differs from Bulletin 118 and the District's original boundary modification request. In general, DWR's proposal reduces the subbasin footprint west of the District's service area by 47,000 acres. Westlands submitted a letter to DWR regarding its proposed changes and recommended that the revisions match the District's service area in the south-west part of the District. Mr. Gutierrez reported that the decision was made based on a technical basis regarding the lack of alluvium.

Additionally, staff was implementing the necessary steps for the District to serve as the Groundwater Sustainability Agency for the Westside Subbasin. Staff would make this formal recommendation to the Board next month, after the District conducts hearings in both Fresno and Kings counties. The Kings County hearing is set for July 13 and the Fresno County hearing will be held in conjunction with the Board's July 19 meeting.

Mr. Gutierrez also reported that the District's groundwater model was in the first phase of development. Phase one includes analyzing and integrating data into GIS and developing the conceptual model of the Westside Subbasin. The District expects the conceptual model to be completed by October 2016 and the groundwater flow model by April 2017.

Meeting Minutes #10

SGMA Excerpt from the July 19, 2016 Board Minutes

This item was covered during the hearing to consider the formation of a Groundwater Sustainability Agency. A summary of the hearing included Resolution 111-16, which authorized District Staff to file as the GSA of the Westside Subbasin. In addition, the hearing provided updates to the status of the Basin Boundary Modification Request and GSP Development.

Meeting Minutes #11

SGMA Excerpt from the August 17, 2016 Board Minutes

Mr. Gutierrez reported that the Board previously authorized staff to submit the District's Basin Boundary Modification Request to DWR. Staff implemented the necessary procedures for the District to serve as the Groundwater Sustainability Agency for the Westside Subbasin. The District's Board held public hearings in Kings County on July 13 and in Fresno County on July 19. At the latter hearing, the Board adopted a resolution electing for the District to serve as the Groundwater Sustainable Agency of the Westside Subbasin. Following this action, staff submitted the District's Groundwater Sustainability Agency formation notification package and DWR posted the District's Groundwater Sustainability Agency notification on August 3, starting the 90-day posting period. DWR is expected to select the District as the exclusive Groundwater Sustainability Agency of the Westside Subbasin on November 1, 2016 if no other eligible, overlapping agency applies for GSA status within the management area. Fresno County is committed to executing a MOU with the District prior to November 1. There were some comments received regarding the recent Stanford University research fellows report on the potential of there being three times more groundwater available than previously suggested. There were many concerns and technical challenges associated with utilizing groundwater resources as an agricultural supply, including water quality, power and water treatment cost and impacts associated with extracting deep groundwater that may exacerbate the Sustainable Groundwater Management Act's undesirable results, namely subsidence. The District would investigate and determine whether the groundwater supply identified by the Stanford study was a sustainable water resource that should be incorporated into the District's water budget and sustainable yield calculation for the District's GSP.

Meeting Minutes #12

SGMA Excerpt from the September 20, 2016 Board Minutes

Mr. Gutierrez reported that the Westside Subbasin Boundary was comprised of approximately of 626,400 acres, including 12,100 acres outside of the District's jurisdictional boundary. Lands outside the District's boundary would be managed under a Memorandum of Understanding with Kings and Fresno Counties. The Water Policy Committee recommended that the Memorandum of Understanding with Fresno County be brought to the Board at next month's meeting for consideration and approval.

Mr. Gutierrez also reported that the District would hold a Sustainable Groundwater Management Workshop on October 31 at the District's Five Points Office.

Meeting Minutes #13

SGMA Excerpt from the October 18, 2016 Board Minutes

Mr. Gutierrez reported that the District executed the Fresno County MOU after recommendation from the Board at the previous Board Meeting. Kings County and the District could not come to an agreement for the MOU.

Mr. Gutierrez reported that the District had a Sustainable Groundwater Management Act workshop scheduled for all water users and landowners on October 31, 2016 at the District's Five Points Office. It will be conducted in order to obtain comments from water users and landowners regarding the items staff should consider in managing the basin going forward.

Meeting Minutes #14

Excerpt from the November 21, 2016 GSA Board Minutes

Mr. Gutierrez reported that the Board approved the Fresno County MOU last month. District staff continued to work with Kings County staff to develop an acceptable MOU for both parties. SGMA does not expand a local agency's authority to impose fees beyond its jurisdictional boundary, so MOUs are necessary for the District to recover costs for managing those areas.

Mr. Gutierrez also reported that the Department of Water Resources designated the District as the exclusive Groundwater Sustainability Agency on November 1, 2016. The District's Groundwater Sustainability Agency notice was posted on DWR's webpage for 90 days and no other eligible, overlapping agency applied for Groundwater Sustainability Agency status. As the Groundwater Sustainability Agency, the District will develop a Groundwater Sustainability Plan that includes a strategy for sustainably managing the subbasin.

The District was in the process of developing the conceptual model of the Westside Subbasin. The conceptual model will explore the potential for extracting groundwater deeper than the base of fresh water. The District's first Groundwater Sustainability Program workshop was held on October 31, 2016 at the District's Five Point Field Office. The District held the workshop to engage the District's water users and interested parties in the GSP development. The main topics of discussion included an overview of the

Sustainable Groundwater Management Agency, a summary of the Groundwater Sustainability Program regulations and development, and solicitation of public input. A considerable amount of comments were received and staff is in the process of going through those comments in order that they may be posted on the District's website.

Mr. Gutierrez stated that the next Groundwater Sustainability Program workshop was scheduled for December 21. The upcoming workshop will be divided into three workshops that focus on the water users within the western, central and eastern hydrogeologic areas of the Westside Subbasin.

Meeting Minutes #15

Excerpt from the December 20, 2016 GSA Board Minutes

Mr. Gutierrez reported that the next Groundwater Sustainability Plan workshop was scheduled for December 21 at the District's Five Points Field Office. The workshop would be divided into three discussions focused on the water users within the western, central and eastern hydrogeologic areas of the Westside Subbasin at 9:00 a.m., 11:00 a.m. and 1:30 p.m., respectively. Following the Sustainable Groundwater Management Act Workshop, staff would hold an Irrigated Lands Regulatory Program workshop to update water users on required reporting and upcoming events for the upcoming year.

Meeting Minutes #16

Excerpt from the January 17, 2017 GSA Board Minutes

Mr. Gutierrez reported that the District held two Groundwater Sustainability Plan Workshops during the month. The workshops were held in order to engage water users and interested parties in the Groundwater Sustainability Plan development. The workshops were divided into three discussions focused on the water users within the western, central and eastern hydrogeologic areas of the Westside Subbasin. Some of the comments received at the workshop included the desire for the development of recharge projects and the creation of an accounting program for allocating groundwater credits for District or privately developed projects. Also expressed was a request to quantify and define the sustainable yields for the upper and lower aquifers by management area and assess the practicality of developing different sustainable yields by management area as compared to having one District-wide sustainable yield. There was also interest in the establishment of a water user technical Groundwater Sustainability Plan group to review information and provide feedback to District staff.

Meeting Minutes #17

Excerpt from the February 28, 2017 GSA Board Minutes

Mr. Gutierrez reported that staff and the consultant continue to work on a groundwater flow model and expect preliminary results to be completed in April. Soon after, staff will schedule another workshop with water users to review those results.

Meeting Minutes #18

Excerpt from the April 18, 2017 GSA Board Minutes

Mr. Gutierrez stated that Fresno County filed to serve as a Groundwater Sustainability Agency for the areas outside the District within Fresno County. This action would not affect the District's ability to enter into an agreement with Fresno County to manage the subbasin. The District was also anticipating preliminary draft results on the groundwater model during the month and would review those results and would provide comments. Future workshops would be scheduled with water users and a technical advisory committee would be developed with some water users in the District to evaluate management options for the plan.

Meeting Minutes #19

Excerpt from the May 16, 2017 GSA Board Minutes

Mr. Gutierrez reported that the Fresno County Board of Supervisors met on May 2, 2017 and agreed to serve as the GSA outside the District's jurisdictional boundaries. The Fresno County Board of Supervisors ratified a Memorandum of Understanding on October 24, 2016 with the District. He also stated that the District continues to work with its consultant to complete the groundwater model with results expected at the end of the week. Preliminary results would be presented to the Board at its next meeting and a workshop for growers who had volunteered to be on the technical committee to review groundwater results would be scheduled.

Meeting Minutes #20

Excerpt from the July 18, 2017 GSA Board Minutes

Mr. Gutierrez reported that the District hosted it first GSP Water User's Technical Advisory Committee on June 22, 2017. Meeting attendance consisted of fourteen water users who farm throughout the District. The discussion was focused on the water user's perspective to GSP development and groundwater management. There was general agreement that actions and concepts should be explored further and include 1) to develop a groundwater credit program that allows water users to transfer or utilize credits in subsequent years; 2) allocate groundwater credits associated with District owned land to water user Eligible Cropland; 3) develop and implement a groundwater replenishment program prior to January 2020 and; 4) develop one sustainable yield number for the entire subbasin and develop management areas and strategies for portions of the subbasin that could exceed the criteria for subsidence, chronic lowering of the groundwater table, groundwater storage loss or water quality degradation.

Mr. Gutierrez also stated that DWR announced GSP development grant funding in June 2017. The District will apply for the grant which allows for a request of up to $1.5 million for GSP development and, if awarded, would need to contribute $1.5 million in matching funds through either in-kind services or case contribution.

Meeting Minutes #21

Excerpt from the October 17, 2017 GSA Board Minutes

Mr. Freeman reported that the District's groundwater model is continuing to be calibrated. There was still some refinement that needed to be done, however, the information shows that the Westside Subbasin's sustainable yield ranges between 195,000 AF to 315,000 AF. The increase over what was typically reported, 200,000 AF to 250,000 AF, was a result of additional capacity that exists for pumping in the upper aquifer. Currently, the District was showing it was an underutilized aquifer, which indicates the quality is not good. Treatment could be an option, however would be expensive to implement. Staff would begin developing scenarios based on the most current information received. Mr. Freeman also stated that the District hosted the second Groundwater Sustainability Plan Water Users Technical Group Meeting. A number of growers and representatives from LNAS attended the meeting which included a presentation from the USGS on subsidence. Finally, the District was working on a grant with DWR to pursue an additional $1 million over and above the $1.5 million previously indicated at last month's board meeting. The additional $1 million was related to disadvantaged communities within the groundwater sustainability basin. The District was also reaching out to disadvantaged communities to involve them in the development of the GSP.

Meeting Minutes #22

Excerpt from the November 21, 2017 GSA Board Minutes

Mr. Freeman reported that the District's groundwater model was in the final stages of development, which includes being calibrated as predicting water elevations in the District with 85% accuracy. He reviewed several graphs with the Board that show some results from the model, including the "Westside Subbasin Annual Groundwater Pumping 1988-2015" and the "Westside Subbasin Annual Change in Groundwater Storage 1988-2015".

After completion of the solute transport modeling, staff would begin modeling different scenarios to optimize groundwater pumping in the subbasin. Since preliminary results are simulating groundwater conditions with a reasonable level of accuracy, the model will serve as a useful tool in developing the Groundwater Sustainability Plan's best management practices.

Mr. Freeman stated that the third Groundwater Sustainability Plan Water User's Technical Group Meeting was scheduled for December 7, 2017. At the meeting, staff would be reviewing DWR's guide for the Best Management Practices for developing sustainable management criteria within a Groundwater Sustainability Plan. The District has approximately two years to adopt the Groundwater Sustainability Plan to meet the January 31, 2020 submittal deadline.

Policy Advocate, Amanda Monaco, with Leadership Counsel for Justice & Accountability, addressed the Board and stated that the Counsel worked with disadvantaged communities in the San Joaquin Valley and Coachella Valley. The Leadership Counsel had been involved with the passage of the Groundwater Sustainability Act legislation and was also involved in disadvantaged communities in the District within the GSP boundaries. She stated that they wished to work with the District and collaborate on community outreach.

Mr. Birmingham stated that the District fully understood the necessity, whether required in the legislation or not, of obtaining the perspective of every interested group, particularly disadvantaged communities on the Westside and greatly appreciated Ms. Monaco's interest and participation in the program.

Meeting Minutes #23

Excerpt from the December 19, 2017 GSA Board Minutes

Mr. Freeman reported that the District's groundwater model continues to go through calibration during the last month and was achieving a 90% accuracy. Going forward, staff will work on the solute transport modeling and evaluate different scenarios to optimize groundwater pumping in the subbasin.

Mr. Freeman also stated that staff submitted a grant package to DWR for preparing the Westside Subbasin GSP and installing groundwater monitoring wells. Staff requested $2.5 million for GSP development and projects. A response was expected at the end of the month.

Mr. Freeman reported that the District hosted a GSP Water Users' Technical Group on December 7, 2017. Staff presented the Best Management Practices for developing Sustainable Management Criteria prepared by DWR. The presentation provided concepts on how the District could incorporate the Best Management Practices into the Groundwater Sustainability Plan. The next workshop will be held in February, 2018.

Meeting Minutes #24

Excerpt from the January 17, 2018 GSA Board Minutes

Mr. Freeman stated a Special Board Meeting will be held on January 22, 2018 to review modeling results with the Board. The Department of Water Resources had not made its decision on the grant applications and anticipated their decision would be announced in February.

Meeting Minutes #25

Excerpt from the March 20, 2018 GSA Board Minutes

Mr. Freeman stated that the District's baseline groundwater model was complete. The baseline model simulates groundwater conditions of the Westside Sub-basin from 1988-2015. Preliminary modeling results indicate that the numeric flow model and solute transport model are simulating groundwater conditions with approximately 90 percent accuracy. Staff will begin modeling different scenarios to optimize groundwater pumping in the sub-basin this month.

Mr. Birmingham added that the baseline groundwater model was prepared for release to the public for review and comment. Once comments were received, the groundwater model would be completed. The model would be released to the public sometime in April.

Mr. Freeman also stated that staff worked with Fresno County to determine five locations to install monitoring wells along the boundary of the Westside and Kings Sub-basins. Construction of the dual completion monitoring wells is scheduled to start in March. The dual completion wells consist of one large borehole designed to accommodate two wells, one well is screened in the upper aquifer and one well is screened in the lower aquifer. Data collected from the monitoring wells will improve the District's understanding of the boundary conditions between the two sub-basins.

Meeting Minutes #26

Excerpt from the April 17, 2018 GSA Board Minutes

Ms. Campbell reported that the District was in the process of developing its Groundwater Sustainability Plan and will have a draft available to the Board by January 2019. A large component of the GSP is public outreach which is being achieved through workshops. On April 6, 2018, the District held its first bilingual workshop and the next workshop will be held the first week of May. The focus of that meeting will be the release of the modeling results. A bilingual workshop with the same information will be held on May 17.

Meeting Minutes #27

Excerpt from the May 15, 2018 GSA Board Minutes

Ms. Campbell gave a progress status report on the Sustainable Groundwater Management Act. Prior month accomplishments included hosting an outreach event on May 3 to present the District's baseline groundwater model results, developing modeling scenarios with the District's consultant to support the GSP management strategies, and meeting with neighboring GSAs to discuss available data and boundary flow methodology. Staff also collaborated with community representatives to release Westlands' GSA Draft Stakeholder Communication and Engagement Plan.

Ms. Campbell also stated that over the next month, the District, in collaboration with the SLDWMA, will hold an outreach event on May 17 in which staff will present the District's baseline groundwater model results in English and Spanish. Staff will also begin monitoring the dual completion wells between Westside and Kings Subbasin boundary constructed by Fresno County, release Westlands' Frequently Ask Questions document, complete the GS P's Administrative Information Section and execute grant agreement with DWR

Ms. Campbell also stated that in the upcoming year, the District will complete the GSP's Plan Area, Basin Settings, Sustainable Management Criteria, Monitoring Networks, Development Projects and Management Actions, Plan Implementation and Final GSP and will also construct four or five monitoring wells with the District's Proposition 1 funding to collect data for the Westside Subbasin. Finally, Ms. Campbell stated that a budget table would be provided that summarizes the budget and expenses for the work related to the preparation of the groundwater model, GSA formation, GSP, and interested party coordination.

Meeting Minutes #28

Excerpt from the June 19, 2018 GSA Board Minutes

Ms. Campbell reported that the District hosted an outreach event on May 17 to present the District's baseline groundwater model results in English and Spanish. District staff has also attended neighboring GSA meetings, continues to share well data with neighbors, released the District's Frequently Asked Questions document and completed the GSP's Administrative Information Section. Upcoming activities include a Special Board Meeting planned to be scheduled on July 16 at Harris Ranch to present Westlands' SGMA groundwater management strategies and GSP development, completion of the GSP's Plan Area and Basin Settings Sections and executing the grant agreement with the Department of Water Resources. Mr. Amaral reported that the District and the San Luis & Delta-Mendota Water Authority held a bi-lingual workshop on SGMA. The next workshop would be held July 16, 2018.

Meeting Minutes #29

Excerpt from the July 17, 2018 GSA Board Minutes

Ms. Campbell reported that the presentation on the Groundwater Sustainability Plan (GSP) would be focused on the overview of proposed groundwater management strategies. She introduced Mr. Scott Slater with Brownstein Hyatt Farber & Schreck, LLP (Brownstein), the District's special counsel assisting with preparation of the GSP. Mr. Slater addressed the Board and water users and stated that the intention for the meeting was to present an overarching strategy for how the District intends to approach the Sustainable Groundwater Management Act (SGMA) process and encouraged input from water users. He further stated that the GSP is being prepared to be adaptable for stakeholders and compliant with SGMA. He reiterated the purpose of SGMA is to promote sustainable management and use of groundwater in a manner that can be maintained without causing undesirable results.

Based on that requirement, the District developed guiding principles which included a dual directive of a) optimizing the reasonable and beneficial use of groundwater; and b) establishing thresholds for protection against undesirable results. Staff believes that inelastic subsidence is the greatest concern and the potential for physical damage within the basin. Mr. Slater further stated that management strategies should achieve the following: accommodate annual variability in groundwater pumping to reflect changes in surface water availability; adaptively manage the basin in response to changing conditions and new information; create clear, transparent rules for basin management; empower stakeholders with the ability to manage their water supplies and make choices; assume the global responsibility for achieving sustainability through cumulative replenishment and enforcement; and maintain a database to account for all water use within the basin.

Mr. Slater continued to state that in order to adhere to the management strategies, the District would establish a groundwater pumping allocation, but the manner in which the allocation would be distributed has not been determined. Options include a single acre- foot per acre District wide allocation, by management area or by subareas depending on geology, hydrology, and basin characteristics. The allocation would be based on the science driven technical data concerning the long-term sustainable recharge rates for the Upper and Lower Aquifers. Mr. Slater also stated that the intention was to not put an annual hard cap on the pumping amount, rather that each water user adhere to a rolling average that would allow for flexibility as long as there is a reconciliation after a certain duration. Beyond that, there would be individual landowner measures and programs to accommodate individual situations and provide for options to recharge the aquifers during wet years. To prevent an unmanageable basin overdraft conditions, the total deficit that a parcel or area could experience would be capped and subject to reconciliation or "true-up" . A true-up date would be established and landowners who had over pumped groundwater would need to supplement their supply with available surface water or acquire groundwater "credits" for neighboring water users. The water user could also address excess groundwater pumping by implementing a groundwater replenishment project to recharge the aquifers. If water users pump less than their allocation, they may be permitted to carry over their allocation.

Since the District does not currently plan to impose annual limitations on groundwater pumping, the discussion turned to an appropriate duration for calculating average pumping volumes and reconciliation periods. Mr. Slater stated it was discussed that 2-5 years could be used for the rolling average. This duration would also work with the 5- year milestone status reviews that the Department of Water Resources will conduct. As the GSP is adaptively managed and revised, the range could adjust. Caps would be put on water debt in this time period so that even though a rolling average is used, a landowner or water user cannot fall behind by more than a specified percentage and the water deficit doesn't shift an excessive burden back to the District. A water user commented that there could be issues if the pay-back period to address the overdraft is too long after reconciliation.

Ms. Campbell continued to report on the various projects the District was considering implementing for augmentation strategies. The District was looking at securing additional surface water to be purchased so that groundwater would not be pumped. An underutilized resource is groundwater pumping from the Upper Aquifer. The Upper Aquifer is not typically pumped in some parts of the District due to water quality, but there are ways to treat the water. Another pilot program was the District's 2017 Aquifer Storage and Recovery Well, which demonstrated that surplus surface water could be injected in the aquifer and recovered later. Finally, the District was looking at groundwater replenishment projects and groundwater banking projects in areas where the Corcoran clay is not present.

In closing, Ms. Campbell reviewed a SGMA timeline. In 2017, the District began its GSP development and held workshops for its GSP development. It was expected that the first draft GSP would be presented to the Board in early 2019 which will continue to go through review with the expectation that a final GSP would go to the Board for adoption in December 2019. The GSP will be presented to the Department of Water Resources in January 2020.

Meeting Minutes #30

Excerpt from the August 14, 2018 GSA Board Minutes

Ms. Campbell provided an update to the board on a groundwater allocation concept. She stated that staff was seeking input on the concept of managing groundwater pumping based on a rolling average, evaluating extraction exceedances and reconciling pumping exceedance by limiting extraction or requiring augmentation. Rolling averages could range from 2, 3, 5 or 10 years. For the meeting, a 3-year average concept was presented. Pumping exceedance, the rolling average extraction and allocation concept, and the allowable pumping exceedance were discussed. Additionally, the Board discussed allocation credits to water users for under pumping. Lastly, staff requested direction from the Board concerning over pumping water allocation and the timeframe for a reconciliation requirement.

The directors concerns with the allocation approach ranged from the potential impact on farming operations if hard limits are placed on groundwater extractions, the potential for some users to pump un-constrained without limits and impact their neighbors, limitations placed on all water users instead of focusing on the sensitive areas along the San Luis Canal, and collateral impacts that an allocation approach has on agricultural related operations dependent on farm commodities.

Meeting Minutes #31

Excerpt from the September 18, 2018 GSA Board Minutes

Ms. Campbell gave a report to the Board on Groundwater Management Strategy Concept, detailing an alternative management strategy and policy direction regarding water level elevation triggers, groundwater status report frequency, pumping exceedance and management strategy preferences. She also provided information on the projected groundwater pumping post GSP, a 3-year groundwater pumping rolling average and identified a pumping deficit/credit for annual and cumulative groundwater pumping. Additionally, she illustrated the potential benefits from replenishment projects. She further stated that a 5-year rolling average and replenishment strategy could be used and highlighted in the feasibility of that strategy.

Ms. Campbell reported on an Alternative Management Strategy that could be used to increase groundwater management flexibility and provide a platform that only restricts pumping when water levels approach minimum threshold levels and allows groundwater pumpers to manage water supplies. She also reported on the Lower Aquifer groundwater level, reviewed cross section along San Luis Canal regarding groundwater elevation and reviewed subsidence concern locations. Finally, she reviewed the accounting requirements under the program which include metering all groundwater wells, imposing restrictions when levels fall below a trigger level and impacts to neighbors.

Meeting Minutes #32

Excerpt from the October 16, 2018 GSA Board Minutes

Ms. Campbell provided a recap of the September SGMA presentation, specifically the strategy for managing allocation and groundwater pumping exceedance. She also presented a revised concept for managing groundwater pumping by management area based upon input from previous meetings and the proxy of focusing on water levels in "green", "yellow" and "red" zones in relations to historical groundwater levels and a possible minimum threshold of 2015 water levels. Ms. Campbell also reported on historical groundwater pumping by Management Areas 1, 2, 3 & 4 from 2012-2017 and discussed historical groundwater levels. In closing, the Board stated that staff should continue exploring management options that promote beneficial use of groundwater to support farming and comply with SGMA.

Meeting Minutes #33

Excerpt from the November 20, 2018 GSA Board Minutes

Ms. Campbell reported the District executed its grant contract with the Department of Water Resources which will enable the District to begin to request grant funding and reimbursement for funds already spent by the District on GSP development to date, totaling approximately $400,000. Additionally, she reported on the potential for four management areas in the District and the concept of limiting groundwater credits. She noted that the management areas included District retired lands. The District will need to determine the policy it will adopt concerning the lands it owns and the groundwater associated with that land. Two options were proposed which included 1) making the groundwater available from District owned land by forbearance and 2) to lease the land and allow tenants to beneficially use groundwater allocations during the term on their lease.

After considerable discussion, the sense of Board was to dismiss Option II and pursue something similar to Option I, including a forbearance option, and present at a future Board meeting how Option I would be implemented.

Ms. Campbell also discussed tiered pricing for groundwater allocation and allowing water users and groundwater pumpers the flexibility to pump more than their groundwater allocation amount when water levels can support it. Fees for one of the tiers would help to establish groundwater replenishment projects. Potential price ranges for replenishment were still being developed. One methodology might be comparable to supplemental water minus energy costs.

Mr. Birmingham concluded that there were costs associated with taking actions to mitigate the effects an individual may have. The costs associated with tier two would be related to the cost to take actions to mitigate the impacts of some entity that has over pumped.

Meeting Minutes #34

Excerpt from the December 18, 2018 GSA Board Minutes

Ms. Campbell recalled the Board previously discussed options concerning allocation of groundwater with the District and reviewed with the Board different groundwater allocation alternatives.

Meeting Minutes #35

Excerpt from the January 15, 2019 GSA Board Minutes

Ms. Campbell gave the Board an update on the Sustainable Groundwater Management Act. Specifically, over the previous month, staff developed future water budget scenarios and based on preliminary model projections, established water level boundary conditions that were consistent with neighboring subbasins which was key to achieving sustainability in the Westside Subbasin. She also stated staff developed a bid specification and environmental documentation to construct five monitoring wells to collect groundwater data for the Westside Subbasin. Finally, staff continued to attend neighboring GSA meetings.

Meeting Minutes #36

Excerpt from the February 19, 2019 GSA Board Minutes

Ms. Campbell reported staff continued to attend neighboring GSA meetings to discuss boundary standards. Concepts developed include consolidation of management areas 2, 3 and 4 and development of an allocation concept to support the uniform allocation for the Upper Aquifer and Lower Aquifer to optimize groundwater supply. Ms. Campbell was provided guidance by the Board on both matters however no action was taken.

Meeting Minutes #37

Excerpt from the April 19, 2019 GSA Board Minutes

Ms. Campbell gave an update to the Board of Directors on the status of the Sustainable Groundwater Management Acct implementation/compliance activities including the development of the groundwater sustainability plan and its potential groundwater management strategies. She gave a brief summary of the April 3 SGMA Workshop in which staff focused on augmentation strategies. Staff provided a forecast of modeling scenarios which included variable acreage, aquifer storage & recovery, full utilization of the upper aquifer and subsidence concern areas along the San Luis Canal. Additionally, staff presented modeling showing support for an annual surface water delivery of 860,000 AF and a sustainable yield number of 250,000 – 300,000 AF. Finally, staff highlighted previous concepts presented to the Board, which included the consolidation of management areas, allocation by aquifer options and management based on water levels.

Meeting Minutes #38

Excerpt from the May 21, 2019 GSA Board Minutes

Ms. Campbell reported on the activities for the month concerning SGMA. Specifically, she stated staff developed a monitoring network of groundwater wells in the Westside Subbasin and stated data collected at each monitoring well would be used to establish a Measurable Objective and Minimum Threshold. Staff also continued to schedule meetings with neighboring GSAs to discuss boundary standards and attend neighboring GSA meetings.

Meeting Minutes #39

Excerpt from the June 24, 2019 GSA Board Minutes

Ms. Campbell reported that, per prior authorization and direction, staff had awarded the monitoring well project to the contractor with the lowest responsive and responsible bid. Staff also coordinated a SGMA meeting with the Leadership Counsel for Justice and Accountability, Fresno County and community members from Cantua Creek and El Porvenir. In addition, Ms. Campbell gave a presentation on the GSP estimated monitoring and implementation costs. Approximately $1.1 million had been spent to date with another $800,000 anticipated to be spent in the near future.

Meeting Minutes #40

Excerpt from the July 16, 2019 GSA Board Minutes

Ms. Campbell gave a presentation on the GSP estimated monitoring and implementation costs. The presentation included three potential rate structures which include land-based charge, volumetric charge or the combination of a land based charge and volumetric charge. The Board requested that Ms. Campbell develop a fourth option for the Board's review next month.

Meeting Minutes #41

Excerpt from the August 20, 2019 GSA Board Minutes

Ms. Campbell reported staff expects to release the Draft Westside Subbasin GSP next month. The hearing for the Draft Westside Subbasin GSP will be on October 30, 2019 at 3:00 p.m. Ms. Campbell also stated the purpose of the presentation was to determine which cost mechanism to incorporate into the GSP implementation. She continued to review the SGMA budget from 2016 until 2020 with the Board and noted $1.5 million of the funds spent on GSP implementation and development have been funded through

Proposition 1 Grant Funding. She reviewed with the Board all GSP related expenses and estimated charge options presenting two different scenarios for charging water users. After discussion, the Board agrees with Ms. Campbell recommendation to implement a land-based charge.

Meeting Minutes #42

Excerpt from the September 17, 2019 GSA Board Minutes

Ms. Campbell reported staff plans to release a draft GSP for review within one week and will conduct workshops to present the GSP in detail. A brief presentation will be provided at the October 15 Regular Board Meeting and also on October 18. Additionally, a public hearing will be held on October 30 at 3:00 p.m. to receive interested party comments concerning the GSP.

Ms. Campbell also stated at the last board meeting, the Board requested that staff evaluate how disadvantaged communities could be affected by the implementation of a land-based charge. The potential revenue from the communities is approximately 0.02% of the total GSP implementation budget, or a about $600.00.

Director Anderson suggested the disadvantaged communities be exempt from that land-based charge and Ms. Campbell stated the item would be addressed during the upcoming hearing.

Meeting Minutes #43

Excerpt from the October 15, 2019 GSA Board Minutes

Ms. Campbell noted Ms. Amy Steinfeld from Brownstein, Hyatt, Farber & Schreck would be assisting her today in the presentation to the Board outlining the Westside Subbasin's Draft Groundwater Sustainability Plan. She stated the Draft Groundwater Sustainability Plan was posted on the District's website. She outlined the discussion concerning Chapters 1-7 which included the history of the Sustainable Groundwater Management Act and its requirement that Groundwater Management Agency's be formed in all medium to high priority basins and develop a Groundwater Sustainability Plan by January 31, 2020 to address undesirable results of groundwater pumping. She also stated the District had hosted 15 public outreach events and provided 43 board updates regarding the District's Groundwater Sustainability Plan. She also outlined the plan area, basin settings and subsidence levels in various areas. Ms. Campbell outlined a monitoring network which included sustainability criteria, undesirable results, minimum thresholds, measurable objectives and groundwater levels.

The project and management actions included in the Draft Groundwater Sustainability Plan: groundwater extraction allocation, aquifer storage and recovery, targeted pumping reduction and recharge basin. She continued to present to the Board incentives to reduce pumping in subsidence sensitive areas.

Ms. Steinfeld outlined the governance chapter, specifically the Rules and Regulations, specific powers as it relates to replenishment, groundwater storage, transfers, accounting and committee formation.

Ms. Campbell concluded the District would hold a workshop on October 18 at 1:30 p.m. and a Board Hearing on October 30 at 3:00 p.m. to receive public comments.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF WESTLANDS WATER DISTRICT, SERVICING AS THE GROUNDWATER SUSTAINABILITY AGENCY OF THE WESTSIDE SUBBASIN

October 30, 2019

A special meeting of the Board of Directors of Westlands Water District, serving as the Groundwater Sustainability Agency of the Westside Subbasin and hearing was called to order by President Peracchi at the District's Five Points Office, 23050 W. Mt. Whitney, Five Points, California at 3:00 p.m.

Directors present:

Don Peracchi, President
William Bourdeau
Frank Coelho
Larry Enos
Dan Errotabere
Ryan Ferguson
Todd Neves

Staff present:

Jose Gutierrez, Chief Operating Officer
Bobbie Ormonde, Deputy General Manager, Finance & Administration/Secretary
Russ Freeman, Deputy General Manager – Resources
Kiti Campbell, Supervisor of Resources
Antonio Solorio, Resources Engineer
Diana Giraldo, Public Affairs Representative

Others present:

Scott Slater, Brownstein, Hyatt, Farber & Shreck
Will Halligan, Luhdorff & Scalmanini

CALL TO ORDER

President Peracchi called the meeting to order.

HEARING TO CONSIDER PUBLIC COMMENT OF THE DRAFT WESTSIDE SUBBASIN GROUNDWATER SUSTAINABILITY PLAN

Ms. Campbell stated staff and consultants would provide a presentation on the District's draft Groundwater Sustainability Plan. She continued to state the presentation would include presentations on the basin setting, monitoring network, projects and management actions, implementation costs and governance. Ms. Campbell outlined chapter 1 of the plan and discussed the Sustainable Groundwater Management Act requirements and stated the District was required to submit and adopt the Groundwater

Sustainability Plan by January 31, 2020 to address undesirable results. She also stated the District had hosted 16 public outreach events and provided 43 board updates.

Ms. Campbell outlined the plan area of the San Joaquin Groundwater Basin and adjacent subbasins which included the Delta-Mendota, Kings, Tulare Lake and Pleasant Valley, groundwater conditions, land use, water supplies and water quality.

Mr. Halligan outlined information on the sustainable yield estimates from historical and projected water budgets, basin settings including information on the aquifer system and subsidence. To address the issues of subsidence, he also outlined a monitoring network in the subbasin that would monitor sustainability criteria, undesirable results, measure minimum threshold and measure objectives. Mr. Halligan stated a monitoring network would be implemented to observe land subsidence and compaction.

Ms. Campbell reported on Project Actions and Management which included the Districts surface water deliveries and years the District expects a CVP or supplemental water supply, groundwater extraction allocation, aquifer storage and recovery, targeted pumping reduction and recharge basins.

Mr. Slater reported on Program Management Element 4 outlined the elements included in this portion of the Groundwater Sustainability Plan as it related to avoiding significant and unreasonable land subsidence.

Ms. Campbell also reported on the annual Groundwater Sustainability Plan monitoring costs, management, administration and other costs, governance and next steps.

PUBLIC COMMENT

Several members of the public made specific comments that will be included in the response to comments that are provided to the public and the GSA Board prior to adoption of the GSP.

ADJOURNMENT

The meeting was adjourned at approximately 4:30 p.m.

Ms. Campbell updated the Board on the Groundwater Sustainability Plan and its potential groundwater management strategies. She stated the District released the draft GSP last month. As a result of the public comment period, the District received 11 comment letters. District staff was working on responding to all comments and potentially updating the GSP if necessary. Additionally, staff developed a Frequently Asked Questions document to address some of the comments publicly. Ms. Campbell also reviewed with the Board a chart of historical groundwater pumping rate of the lower aquifer from 2010-2019. Responses to comments by the public on the GSP were being evaluated by staff and would be considered by the Board before the GSP was adopted. Ms. Campbell stated the deadline for the GSP to be approved was January 31, 2020.

Consider that the Board of Directors of Westlands Water District, Serving as the Groundwater Sustainability Agency of the Westside Subbasin, Adopt Resolution No. GSA-101-19, thereby, Authorizing the Submission of an Application and Proposal for Grant Funding from the California Department of Water Resources for Groundwater Sustainability Plan Implementation of a Metering and Advanced Metering Infrastructure Network, and Ground Elevation Benchmark Network

Ms. Campbell reported the purpose of this item is to request that the Board adopt Resolution No. GSA-101-19 authorizing the submission of an application to the California Department of Water Resources Sustainable Groundwater Management Grant Program. The Westlands Water District Groundwater Sustainability Agency is eligible to submit a grant application to fund the installation of groundwater meters and expanding the groundwater elevation monitoring network. The grant requires that the costs are spent between June 2018 through April 2022. The proposed funding plan includes the GSA's contribution of $261,000 and the grant funding request for $500,000 from DWR. In order to complete the application, the GSA's Board is required to adopt a resolution authorizing a representative to submit the application and execute an agreement with the State of California for a SGM Planning – Round 3 grant application.

Upon motion duly made and seconded, the Board of Directors of Westlands Water District, serving as the Groundwater Sustainability Agency of the Westside Subbasin adopted Resolution No. GSA 101-19 authorizing the submission of an application and proposal for grant funding from the SGM Grant Program

Planning Grant and authorizing the General Manager or his designee to execute the necessary funding agreements, in substantially the same form as presented; provided that the General Manager or General Counsel may revise the Resolution as required. After the vote, Mr. Birmingham announced that the Board approved the action with the vote as follows:

President Peracchi: Aye

Director Anderson: Absent

Director Bourdeau: Aye

Director Coelho: Aye

Director Enos: Aye

Director Errotabere: Absent

Director Ferguson: Aye

Director Nunn: Aye

Director Neves: Aye

Meeting Minutes #46

Excerpt from the December 17, 2019 GSA Board Minutes

Approved Minutes are not available.

Meeting Minutes #47

Excerpt from the December 18, 2019 GSA Board Minutes

Approved Minutes are not available.

Meeting Minutes #48

Excerpt from the January 8, 2020 GSA Board Minutes

Approved Minutes are not available.

Draft GSP Comments Received

Comment Period ended on October 31, 2019

#	Commenter
1	The Nature Conservancy
2	Maricopa, Woolf, & Mike Henry
3	Leadership Counsel -1
4	Leadership Counsel -2
5	KRWA
6	Wonderful Orchards
7	North Fork Kings GSA
8	North Kings GSA
9	The Nature Conservancy, Audubon California, Clean Water Action, Clean Water Fund, and Local Government Commission
10	Robert Urban
11	California Fish and Wildlife (November 7, 2019)
12	Robert Urban
13	Greg Milton
14	Amanda Monaco (Nov 17, 2019)
15	Mike Henry (Nov 17, 2019)
16	LNAS (Dec 19, 2019)
17	Water User Comment
18	Fresno County Letter of Support (Dec 17, 2019)
19	Water Wise (Dec 23, 2019)
20	Department of Water Resources State Water Project (Dec 26, 2019)

The Nature Conservancy
Protecting nature. Preserving life.

CALIFORNIA WATER | **GROUNDWATER**

555 Capitol Mall, Suite 1290
Sacramento, California 95814
[916] 449-2850

nature.org
GroundwaterResourceHub.org

October 31, 2019

Katarina Campbell
Westlands Water District
3130 North Fresno Street, P.O. Box 6056
Fresno, CA 93703

Submitted online via: https://wwd.ca.gov/draft-gsp/

Re: Public Draft Groundwater Sustainability Plan for Westlands Water District, Westside Subbasin

Dear Ms. Campbell,

The Nature Conservancy (TNC) appreciates the opportunity to comment on the Groundwater Sustainability Plan for the Westlands Water District's GSP that is being prepared under the Sustainable Groundwater Management Act (SGMA).

TNC as a Stakeholder Representative for the Environment

TNC is a global, nonprofit organization dedicated to conserving the lands and waters on which all life depends. We seek to achieve our mission through science-based planning and implementation of conservation strategies. For decades, we have dedicated resources to establishing diverse partnerships and developing foundational science products for achieving positive outcomes for people and nature in California. TNC was part of a stakeholder group formed by the Water Foundation in early 2014 to develop recommendations for groundwater reform and actively worked to shape and pass SGMA.

Our reason for engaging is simple: California's freshwater biodiversity is highly imperiled. We have lost more than 90 percent of our native wetland and river habitats, leading to precipitous declines in native plants and the populations of animals that call these places home. These natural resources are intricately connected to California's economy providing direct benefits through industries such as fisheries, timber and hunting, as well as indirect benefits such as clean water supplies. SGMA must be successful for us to achieve a sustainable future, in which people and nature can thrive within the Westlands Water District and California.

We believe that the success of SGMA depends on bringing the best available science to the table, engaging all stakeholders in robust dialog, providing strong incentives for beneficial outcomes and rigorous enforcement by the State of California.

Given our mission, we are particularly concerned about the inclusion of nature, as required, in GSPs. TNC has developed a suite of tools based on best available science to help Groundwater Sustainability Agencies (GSAs), consultants, and stakeholders efficiently incorporate nature into GSPs. These tools and resources are available online at

GroundwaterResourceHub.org. TNC's tools and resources are intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

Addressing Nature's Water Needs in GSPs

SGMA requires that all beneficial uses and users, including environmental users of groundwater, be considered in the development and implementation of GSPs (Water Code § 10723.2).

The GSP Regulations include specific requirements to identify and consider groundwater-dependent ecosystems (GDEs) [23 CCR §354.16(g)] when determining whether groundwater conditions are having potential effects on beneficial uses and users. GSAs must also assess whether sustainable management criteria may cause adverse impacts to beneficial uses and users, which include environmental uses, such as plants and animals. TNC has identified each part of GSPs where consideration of beneficial uses and users are required. That list is available here: https://groundwaterresourcehub.org/importance-of-gdes/provisions-related-to-groundwater-dependent-ecosystems-in-the-groundwater-s. Please ensure that environmental beneficial users are addressed accordingly throughout the GSP. Adaptive management is embedded within SGMA and provides a process to work toward sustainability over time by beginning with the best available information to make initial decisions, monitoring the results of those decision, and using data collected through monitoring to revise decisions in the future. Over time, GSPs should improve as data gaps are reduced and uncertainties addressed.

To help ensure that GSPs adequately address nature as required under SGMA, TNC has prepared a checklist (**Attachment A**) for GSAs and their consultants to use. TNC believes the following elements are foundational for 2020 GSP submittals. For detailed guidance on how to address the checklist items, please also see our publication, *GDEs under SGMA: Guidance for Preparing GSPs*[1].

1. Environmental Representation

SGMA requires that GSAs consider the interests of all beneficial uses and users of groundwater. To meet this requirement, we recommend actively engaging environmental stakeholders by including environmental representation on the GSA board, technical advisory group, and/or working groups. This could include local staff from state and federal resource agencies, nonprofit organizations and other environmental interests. By engaging these stakeholders, GSAs will benefit from access to additional data and resources, as well as a more robust and inclusive GSP.

2. Basin GDE and ISW Maps

SGMA requires that GDEs and interconnected surface waters (ISWs) be identified in the GSP. We recommend using the Natural Communities Commonly Associated with Groundwater Dataset (NC Dataset) provided online[2] by the Department of Water Resources (DWR) as a starting point for the GDE map. The NC Dataset was developed through a collaboration between DWR, the California Department of Fish and Wildlife (CDFW) and TNC. We also recommend using GDE Pulse, which is also available on the internet at https://gde.codefornature.org/#/home. We also recommend using the California Natural

[1] GDEs under SGMA: Guidance for Preparing GSPs is available at: https://groundwaterresourcehub.org/public/uploads/pdfs/GWR_Hub_GDE_Guidance_Doc_2-1-18.pdf

[2] The Department of Water Resources' Natural Communities Commonly Associated with Groundwater dataset is available at: https://gis.water.ca.gov/app/NCDatasetViewer/

Diversity Database (CNDDB) provided by CDFW to look up species occurrences within your area.

3. Potential Effects on Environmental Beneficial Users

SGMA requires that potential effects on GDEs and environmental surface water users be described when defining undesirable results. In addition to identifying GDEs in the basin, TNC recommends identifying beneficial users of surface water, which include environmental users. This is a critical step, as it is impossible to define "significant and unreasonable adverse impacts" without knowing *what* is being impacted. For your convenience, we've provided a list of freshwater species within the boundary of the Westside Groundwater Subbasin (Subbasin) in **Attachment C**. Our hope is that this information will help your GSA better evaluate the impacts of groundwater management on environmental beneficial users of surface water. We recommend that after identifying which freshwater species exist in your basin, especially federal- and state-listed species, that you contact staff at CDFW, United States Fish and Wildlife Service (USFWS) and/or National Marine Fisheries Services (NMFS) to obtain their input on the groundwater and surface water needs of the organisms on the GSA's freshwater species list. We also refer you to the Critical Species Lookbook[3] prepared by TNC and partner organizations for additional background information on the water needs and groundwater reliance of critical species. Since effects to plants and animals are difficult and sometimes impossible to reverse, we recommend erring on the side of caution to preserve sufficient groundwater conditions to sustain GDEs and ISWs.

4. Biological and Hydrological Monitoring

If sufficient hydrological and biological data in and around GDEs is not available in time for the 2020/2022 plan, data gaps should be identified along with actions to reconcile the gaps in the monitoring network.

TNC has reviewed the Westlands Water District Draft GSP and appreciates the use of some our relevant resources in addressing GDE-related topics. However, we consider it to be **inadequate** under SGMA since key environmental beneficial uses and users are not adequately identified and considered. In particular, 1) ISWs and GDEs are not adequately identified and evaluated for ecological importance or adequately considered in the basin's sustainable management criteria, and 2) connectivity of ISWs and GDEs with the Shallow Zone and Upper Aquifer was not characterized. **Please present a more thorough analysis of the 1) connectivity of the Shallow Zone and Upper Aquifer, and 2) identification and evaluation of ISWs and GDEs in subsequent drafts of the GSP**. **Once potential GDEs and ISWs are identified, they must be considered when defining undesirable results and evaluated for further monitoring needs until data gaps are filled in the future**.

Our specific comments related to the Westlands Water District GSP are provided in detail in **Attachment B** and are in reference to the numbered items in **Attachment A. Attachment C** provides a list of the freshwater species located in the Subbasin. **Attachment D** describes six best practices that GSAs and their consultants can apply when using local groundwater data to confirm a connection to groundwater for DWR's NC Dataset. **Attachment E** provides an overview of a new, free online tool (i.e., GDE Pulse) that allows GSAs to assess changes in GDE health using satellite, rainfall, and groundwater data.

Thank you for fully considering our comments as you develop your GSP.

---

[3] Available online at: https://groundwaterresourcehub.org/sgma-tools/the-critical-species-lookbook/

Best Regards,

Sandi Matsumoto
Associate Director, California Water Program
The Nature Conservancy

Attachment A

Environmental User Checklist

The Nature Conservancy is neither dispensing legal advice nor warranting any outcome that could result from the use of this checklist. Following this checklist does not guarantee approval of a GSP or compliance with SGMA, both of which will be determined by DWR and the State Water Resources Control Board.

GSP Plan Element*		GDE Inclusion in GSPs: Identification and Consideration Elements	Check Box
Admin Info	**2.1.5 Notice & Communication** *23 CCR §354.10*	**Description of the types of environmental beneficial uses of groundwater that exist within GDEs and a description of how environmental stakeholders were engaged throughout the development of the GSP.**	1
Planning Framework	**2.1.2 to 2.1.4 Description of Plan Area** *23 CCR §354.8*	**Description of jurisdictional boundaries, existing land use designations, water use management and monitoring programs; general plans and other land use plans relevant to GDEs and their relationship to the GSP.**	2
		Description of instream flow requirements, threatened and endangered species habitat, critical habitat, and protected areas.	3
		Summary of process for permitting new or replacement wells for the basin, and how the process incorporates any protection of GDEs	4
Basin Setting	**2.2.1 Hydrogeologic Conceptual Model** *23 CCR §354.14*	**Basin Bottom Boundary:** Is the bottom of the basin defined as at least as deep as the deepest groundwater extractions?	5
		Principal aquifers and aquitards: Are shallow aquifers adequately described, so that interconnections with surface water and vertical groundwater gradients with other aquifers can be characterized?	6
		Basin cross sections: Do cross-sections illustrate the relationships between GDEs, surface waters and principal aquifers?	7
	2.2.2 Current & Historical Groundwater Conditions *23 CCR §354.16*	**Interconnected surface waters:**	8
		Interconnected surface water maps for the basin with gaining and losing reaches defined (included as a figure in GSP & submitted as a shapefile on SGMA portal).	9
		Estimates of current and historical surface water depletions for interconnected surface waters quantified and described by reach, season, and water year type.	10
		Basin GDE map included (as figure in text & submitted as a shapefile on SGMA Portal).	11

		If NC Dataset *was* used:	Basin GDE map denotes which polygons were kept, removed, and added from NC Dataset (Worksheet 1, can be attached in GSP section 6.0).	12
			The basin's GDE shapefile, which is submitted via the SGMA Portal, includes two new fields in its attribute table denoting: 1) which polygons were kept/removed/added, and 2) the change reason (e.g., why polygons were removed).	13
			GDEs polygons are consolidated into larger units and named for easier identification throughout GSP.	14
		If NC Dataset *was not* used:	Description of why NC dataset was not used, and how an alternative dataset and/or mapping approach used is best available information.	15
		Description of GDEs included:		16
		Historical and current groundwater conditions and variability are described in each GDE unit.		17
		Historical and current ecological conditions and variability are described in each GDE unit.		18
		Each GDE unit has been characterized as having high, moderate, or low ecological value.		19
		Inventory of species, habitats, and protected lands for each GDE unit with ecological importance (Worksheet 2, can be attached in GSP section 6.0).		20
	2.2.3 Water Budget *23 CCR §354.18*	Groundwater inputs and outputs (e.g., evapotranspiration) of native vegetation and managed wetlands are included in the basin's historical and current water budget.		21
		Potential impacts to groundwater conditions due to land use changes, climate change, and population growth to GDEs and aquatic ecosystems are considered in the projected water budget.		22
Sustainable Management Criteria	**3.1 Sustainability Goal** *23 CCR §354.24*	**Environmental stakeholders/representatives were consulted.**		23
		Sustainability goal mentions GDEs or species and habitats that are of particular concern or interest.		24
		Sustainability goal mentions whether the intention is to address pre-SGMA impacts, maintain or improve conditions within GDEs or species and habitats that are of particular concern or interest.		25
	3.2 Measurable Objectives *23 CCR §354.30*	**Description of how GDEs were considered and whether the measurable objectives and interim milestones will help achieve the sustainability goal as it pertains to the environment.**		26
	3.3 Minimum Thresholds *23 CCR §354.28*	**Description of how GDEs and environmental uses of surface water were considered when setting minimum thresholds for relevant sustainability indicators:**		27
		Will adverse impacts to GDEs and/or aquatic ecosystems dependent on interconnected surface waters (beneficial user of surface water) be avoided with the selected minimum thresholds?		28
		Are there any differences between the selected minimum threshold and state, federal, or local standards relevant to the species or habitats residing in GDEs or aquatic ecosystems dependent on interconnected surface waters?		29
	3.4 Undesirable Results *23 CCR §354.26*	**For GDEs, hydrological data are compiled and synthesized for each GDE unit:**		30
		If hydrological data *are available* within/nearby the GDE	Hydrological datasets are plotted and provided for each GDE unit (Worksheet 3, can be attached in GSP Section 6.0).	31
			Baseline period in the hydrologic data is defined.	32

			GDE unit is classified as having high, moderate, or low susceptibility to changes in groundwater.	33
			Cause-and-effect relationships between groundwater changes and GDEs are explored.	34
		If hydrological data *are not available* within/nearby the GDE	Data gaps/insufficiencies are described.	35
			Plans to reconcile data gaps in the monitoring network are stated.	36
		For GDEs, biological data are compiled and synthesized for each GDE unit:		37
		Biological datasets are plotted and provided for each GDE unit, and when possible provide baseline conditions for assessment of trends and variability.		38
		Data gaps/insufficiencies are described.		39
		Plans to reconcile data gaps in the monitoring network are stated.		40
		Description of potential effects on GDEs, land uses and property interests:		41
		Cause-and-effect relationships between GDE and groundwater conditions are described.		42
		Impacts to GDEs that are considered to be "significant and unreasonable" are described.		43
		Known hydrological thresholds or triggers (e.g., instream flow criteria, groundwater depths, water quality parameters) for significant impacts to relevant species or ecological communities are reported.		44
		Land uses include and consider recreational uses (e.g., fishing/hunting, hiking, boating).		45
		Property interests include and consider privately and publicly protected conservation lands and opens spaces, including wildlife refuges, parks, and natural preserves.		46
Sustainable Management Criteria	**3.5 Monitoring Network** *23 CCR §354.34*	Description of whether hydrological data are spatially and temporally sufficient to monitor groundwater conditions for each GDE unit.		47
		Description of how hydrological data gaps and insufficiencies will be reconciled in the monitoring network.		48
		Description of how impacts to GDEs and environmental surface water users, as detected by biological responses, will be monitored and which GDE monitoring methods will be used in conjunction with hydrologic data to evaluate cause-and-effect relationships with groundwater conditions.		49
Projects & Mgmt Actions	**4.0. Projects & Mgmt Actions to Achieve Sustainability Goal** *23 CCR §354.44*	Description of how GDEs will benefit from relevant project or management actions.		50
		Description of how projects and management actions will be evaluated to assess whether adverse impacts to the GDE will be mitigated or prevented.		51

* In reference to DWR's GSP annotated outline guidance document, available at: https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/GD_GSP_Outline_Final_2016-12-23.pdf

Attachment B

TNC Evaluation of the
Westlands Water District Groundwater Sustainability Plan, Public Review Draft

A complete draft of the Westlands Water District's GSP is available at https://wwd.ca.gov/draft-gsp/ for public review and comment. The GSP publication date is not provided. This attachment summarizes our comments on the complete public draft GSP. Comments are provided in the order of the checklist items included as Attachment A.

Checklist Item 1 - Notice & Communication (23 CCR §354.10) **1-1**

[Section 2.1.5.1 Identification of Groundwater Beneficial Uses/Stakeholders (p. 2-17)]

- California Water Code §1305(f) defines that beneficial uses of waters of the State include "preservation and enhancement of fish, wildlife, and other aquatic resources and preserves". Section 2.1.5.1 lists typical users of groundwater, including agricultural, domestic, municipal, the public, agencies, federal government, disadvantaged communities, and environmental users. Environmental users listed were the Pilibos Wildlife Area and the Pleasant Valley Ecological Area. **Please describe whether other beneficial uses and users of groundwater in the Subbasin are present, such as: GDEs; managed wetlands; Protected Lands, including conservation areas and other protected lands; and Public Trust Uses including wildlife, aquatic habitat, fisheries, and recreation.**
- The types and locations of environmental uses, species and habitats supported, and the designated beneficial environmental uses and users of surface waters that may be affected by groundwater extraction in the Subbasin should be specified. **Please explicitly identify the environmental users and take particular note of the species with protected status.** The following are resources that can be used:
  - Natural Communities Commonly Associated with Groundwater dataset (NC Dataset) - https://gis.water.ca.gov/app/NCDatasetViewer/
  - The list of freshwater species located in the Westside Subbasin in Attachment C of this letter.
  - The California Department of Fish and Wildlife's California Natural Diversity Database (CNDDB).

Checklist Items 2 to 4 - Description of general plans and other land use plans relevant to GDEs and their relationship to the GSP (23 CCR §354.8) **1-2**

[Section 2.1 Description of the Plan Area (pp. 2-1 to 2-5)]

- The GSP provides a description of the Central Valley Project and groundwater well density, however there is no discussion of any instream flow requirements, if any, or how the water infrastructure is in compliance with regulatory requirements set to protect species of concern. **Please provide a description of any current and planned instream flow requirements for the westside creeks including Panoche Creek, Cantua Creek, Salt, Martinez, Domengine, the Arroyo**

Pasajero (Los Gatos and Zapato Chino Creeks). If there are not instream flow requirements in place or planned, then please state that in the document.

[Section 2.1.6 Land Use Elements or Topic Categories of Applicable General Plans (p. 2-6 to 2-9)] **1-3**

- This section is focused on agriculture and irrigation needs, demands, and types of irrigation. In general, the general plans do seek to protect riparian habitat. This section should identify Habitat Conservation Plans (HCPs) or Natural Community Conservation Plans (NCCPs) within the Subbasin and if they are associated with areas with instream flow requirements; or critical, GDE or ISW habitats. **Please identify all relevant HCPs and NCCPs within the Subbasin, and any reaches with instream flow and critical habitat requirements. Please elaborate on the natural resources within the Subbasin and address how GSP implementation will coordinate with the goals of these plans and requirements.**
- The Critical Species Lookbook[4] includes the potential groundwater reliance of critical species in the basin. **Please include a discussion regarding the management of critical species and their habitats for these aquatic ecosystems and its relationship to the GSP.**

[Section 2.1.3.5 General Plan Considerations (p. 2-9)] **1-4**

- There are no figures that show the proportion of the area covered by city, community, and county general plans. There are two county plans and two city plans that cover the Westlands Water District's area. The GSP should be modified to include a discussion of General Plan goals and policies related to the protection and management of GDEs, ISWs and aquatic resources that could be affected by groundwater withdrawals. **Please include a discussion of how implementation of the GSP may affect and be coordinated with General Plan policies and procedures regarding the protection of wetlands, aquatic resources and other GDEs and ISWs.**

[Section 2.1.4.1 County Well Construction, Well Destruction and Abandonment Policies (p. 2-14)] **1-5**

Table 2-7 (p. 2-14) summarizes well permitting requirements and county ordinances for the counties of Fresno and Kings. **Please include a discussion of the following in this section:**

- Future well permitting must be coordinated with the GSP to assure achievement of the Plan's sustainability goals.
- The State Third Appellate District recently found that Counties have a responsibility to consider the potential impacts of groundwater withdrawals on public trust resources when permitting new wells near streams with public trust uses (ELF v.

[4] Available online at: https://groundwaterresourcehub.org/sgma-tools/the-critical-species-lookbook/

SWRCB and Siskiyou County, No. C083239). **The need for well permitting programs to comply with this requirement should be stated in the text.**

Checklist Items 5 to 7 – Hydrogeologic Conceptual Model (23 CCR §354.14) 1-6

[Section 2.2.3 Hydrogeological Conceptual Model (p. 2-21)]

- Defining the bottom of the Subbasin based on geochemical properties is a suitable approach for defining the base of freshwater, however, as noted on page 9 of DWR's Hydrogeologic Conceptual Model BMP (https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_HCM_Final_2016-12-23.pdf) "the definable bottom of the basin should be at least as deep as the deepest groundwater extractions". **Thus, groundwater extraction well depth data should also be included in the determination of the basin bottom.** This will prevent the possibility of extractors with wells deeper than the basin boundary (defined by the base of freshwater) from claiming exemption of SGMA due to their well residing outside the vertical extent of the basin boundary. **Please characterize groundwater well extractions from the deepest wells in relation to defining the basin bottom**.

[Section 2.2.1.1 Background Information for Hydrogeologic Model (p. 2-27)] 1-7

- Regional basin-wide geologic cross sections are provided in Figures 2-27 through 2-30 (pp. 2-28 to 2-30, Chapter 2 figures). These cross-sections do not include a graphical representation of the manner in which the very shallow groundwater or perched water may interact with ISWs or GDEs that would allow the reader to understand this topic. **Please include example near-surface cross section details that depict the conceptual understanding of shallow groundwater and stream interactions at different locations, including the Shallow Zone, any perched aquifers, and the Upper Aquifer**.
- Much of the referenced information that was relied on for this GSP is pre-1980; however, the water districts and DWR have been closely monitoring the Subbasin. More information should be presented that represent current, as well as historical conditions. **Please elaborate further on current conditions and how conditions have changed from the historical baseline.**

[Section 2.2.1.6 Identification / Differentiation of Hydrogeologic Units (pp. 2-27 to 2-32)] 1-8

- Although there is robust description of the Upper and Lower Aquifers there is no explicit description or supporting data and information of how the Shallow Zone of the Upper Aquifer is not influenced by pumping in the Upper Aquifer. DWR's definition of a principal aquifer, is defined as an "aquifer or aquifer system that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems" [*23 CCR §351(aa)*]. The Shallow Zone of the Upper Aquifer may provide water supply to GDEs and ISWs. **Please explicitly state which is the principal aquifer, and expand the description of the principal aquifer and aquitards to include the Shallow Zone.**

[Section 2.2.3.6.3 Upper Aquifer (p. 2-30)] 1-9

- The Upper Aquifer is overlain by a shallow zone that appears to occasionally be near or at the ground surface. There is a lack of information detailing and describing this shallow zone, and its connection to the Upper Aquifer. **Include a discussion of the relationship between the Shallow Zone and Upper Aquifer, and provide cross-sections to show their connectivity and relationship to potential ISWs and GDEs.**

[Section 2.2.4.1.1 Historical Groundwater Levels (pp. 2-34 to 2-35)] 1-10

- Water surface elevations are shown for select wells for the Upper and Lower Aquifers (Figures 2-33 and 2-34); however, no data is shown that clearly identifies the relationship between the Shallow Zone and Upper Aquifer. **Please identify this as a data gap and explain how this data gap will be filled in the future.**

[Section 2.2.2.3 Subsurface Compaction and Land Subsidence (p. 2-38)] 1-11

- The GSP states that “The majority of irrigation water is pumped from the Lower Aquifer due to its greater thickness and because of the better water quality and well yields compared to the Upper Aquifer”. Due to the generally shallow nature and higher salinity, very shallow groundwater is not used to provide a major supply of water for agricultural or drinking uses within the Subbasin, although some projects are being developed to reuse this water on more salt-tolerant crops. Even if the GSA doesn’t define this as principal aquifer, the text indicates current or future use that could threaten ISWs and GDEs and should therefore be considered in the sustainability criteria. **Furthermore, Figures 2-43 to 2-45 show a reduction in TDS from 1990 to 2015. Thus, disregarding this shallow groundwater as a principal aquifer due to its water quality is inadequate.** This is especially true in the places where projects to extract the shallow groundwater may be considered for use on more salt-tolerant crops. SGMA requires GSAs to sustainably manage groundwater resources in all aquifers, especially if groundwater use and management can result in impacts on beneficial uses and users. Please refer to Best Practice #1 in Attachment D for further explanation and accompanying graphics.

<u>Checklist Items 8 to 10 – Interconnected Surface Waters (ISW) (23 CCR §354.16)</u> 1-12

[Section 2.2.4.4.1 Natural Surface Water Features and Flow (pp. 2-42 to 2-43)]

- The regulations [23 CCR §351(o)] define ISWs as “surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted”. “At any point” has both a spatial and temporal component. Even short durations of interconnections of groundwater and surface water can be crucial for surface water flow and supporting environmental users of groundwater and surface water. ISWs can be either gaining or losing. The text states (p. 2-42) that “Based on an evaluation of Upper Aquifer groundwater levels and contours of depth to groundwater, groundwater levels underlying the intermittent streams during the 2015 baseline period demonstrates that the streams are not interconnected with the groundwater system". However, this conclusion is based entirely on the Upper Aquifer, disregarding the Shallow Zone of the Upper Aquifer. No evidence is provided in the GSP that states that these streams are not connected to the Upper Aquifer along some portion of the drainage for some time period. **Please provide data or analysis to back up the statement that these westside streams do not represent areas of potential GDEs or ISWs. Please reconcile data gaps (shallow monitoring wells, stream gauges, and nested/clustered wells) along surface water features in the Monitoring Network section of the GSP to improve identification of ISWs prior to disregarding them in the GSP.**

<u>Checklist Items 11 to 15 – Identifying and Mapping GDEs (23 CCR §354.16)</u> **1-13**

[Section 2.2.4.4.5 Groundwater Dependent Ecosystems (p. 2-44)]

- The text states (p. 2-44): "The first recommended step to determine whether the TNC potential GDEs exist was to evaluate depth to water in the Upper Aquifer using 30 ft bgs as a threshold." However, this evaluation potentially misses GDEs due to the potential for GDEs to utilize the Shallow Zone of the Upper Aquifer. The following comments apply to *areas with depth to groundwater greater than 30 feet in winter 2014 to 2015:*
    - o While depth to groundwater levels within 30 feet are generally accepted as being a proxy for deciding if polygons in the NC dataset are connected to groundwater, it is highly advised that seasonal and interannual groundwater fluctuations in the groundwater regime are taken into consideration. Utilizing groundwater data from one point in time (e.g., Winter 2014 to 2015) can misrepresent groundwater levels required by GDEs, and inadvertently result in adverse impacts to the GDEs. Based on a study we recently submitted to *Frontiers in Environmental Science*, we've observed riparian forests along the Cosumnes River to experience a range in groundwater levels between 1.5 and 75 feet over seasonal and interannual timescales. Seasonal fluctuations in the regional water table can support perched groundwater near an intermittent river that seasonally runs dry due to such fluctuations. While perched groundwater itself cannot directly be managed due to its position in the vadose zone, the water table position within the regional aquifer (via pumping rate restrictions, restricted pumping at certain depths, restricted pumping around GDEs, well density rules, etc.) and its interactions with surface water (e.g., timing and duration) can be managed to prevent adverse impacts to ecosystems due to changes in groundwater quality and quantity under SGMA. **We highly recommend using depth to groundwater data from multiple seasons and water year types (e.g., wet, dry, average, drought) to determine the range of depth to groundwater around NC dataset polygons. Please refer to Attachment D of this letter for best practices for using local groundwater data to verify whether polygons**

in the NC Dataset are supported by groundwater in an aquifer. If insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset, include those polygons in the GSP until data gaps are reconciled in the monitoring network.

- If there are insufficient groundwater level data in the Shallow Zone, then the NCCAGs in these areas should be included as GDEs in the GSP until data gaps are reconciled in the monitoring network. **Confirmation of GDEs should be done using depth to groundwater in the Shallow Zone. Please revise the GDE analysis in the GSP.**
- **Please provide depth to groundwater contour maps and note the following best practices for doing so.**
  - Are the wells used for interpolating depth to groundwater sufficiently close (<5km) to NC Dataset polygons to reflect local conditions relevant to ecosystems?
  - Are the wells used for interpolating depth to groundwater screened within the surficial unconfined aquifer and capable of measuring the true water table?
  - Is depth to groundwater contoured using groundwater elevations at monitoring wells to get groundwater elevation contours across the landscape? This layer can then be subtracted from land surface elevations from a Digital Elevation Model (DEM) to estimate depth-to-groundwater contours across the landscape. This will provide much more accurate contours of depth to groundwater along streams and other land surface depressions where GDEs are commonly found. Depth to groundwater contours developed from depth to groundwater measurements at wells assumes that the land surface is constant, which is a poor assumption to make. It is better to assume that water surface elevations are constant in between wells, and then calculate depth to groundwater using a DEM of the land surface to contour depth to groundwater.
- **Please indicate what vegetation is present in the potential GDEs, and whether the GDE was eliminated or retained based solely on the 30-foot depth limit.** Please use care when considering rooting depths of vegetation**.** While Valley Oak (*Quercus lobata*) have been observed to have a max rooting depth of ~24 feet (https://groundwaterresourcehub.org/gde-tools/gde-rooting-depths-database-for-gdes/), rooting depths are likely to spatially vary based on the local hydrologic conditions available to the plant. Also, max rooting depths do not take capillary action into consideration, which will vary with soil type and is an important consideration since woody phreatophytes generally do not prefer to have their roots submerged in groundwater for extended periods of time, and hence effectively redistribute their root systems to straddle the water table as it fluctuates. Hence, being highly capable of accessing groundwater at much deeper depths when needed.

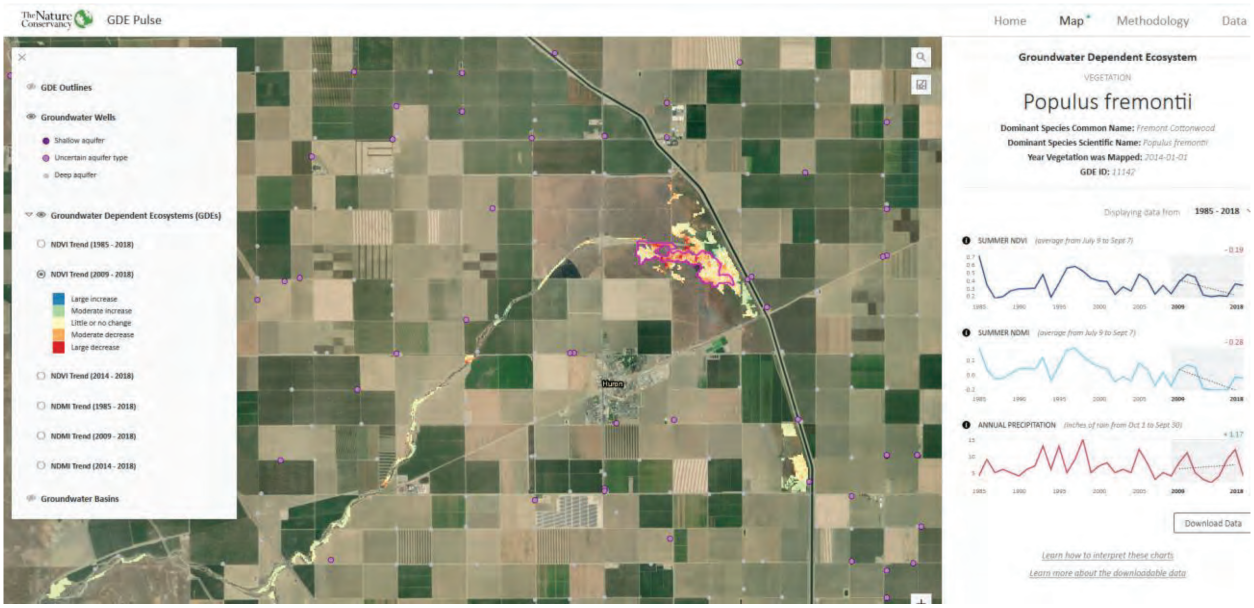
- GDEs can rely on multiple water sources simultaneously and at different temporal and / or spatial scales (e.g., precipitation, river water, reservoir water, soil moisture in the vadose zone, groundwater, applied water, treated wastewater effluent, urban stormwater, irrigated return flow). Rohde, Froend and Howard (2017) acknowledged GDEs as ecosystems that can rely on groundwater for some or all of their requirements. This publication can be found at: https://ngwa.onlinelibrary.wiley.com/doi/pdf/10.1111/gwat.12511. SGMA (Section 351.0) defines GDEs as "ecological communities and species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface". **Hence, we recommend using depth to groundwater contour maps derived from subtracting groundwater levels from a DEM, as described above, to identify whether a connection to groundwater exists for the wetlands mapped in Figure 2-14 in the Subbasin. Please refer to Attachments D and E of this letter for best practices for using local groundwater data to 1) verify whether polygons in the NC Dataset are supported by groundwater in an aquifer, and 2) verify ecosystem decline or recovery is correlated with groundwater levels.**

- The GSP states, "…GDEs are sparse and cover small areas, primarily occurring along ephemeral streams in the western portion of the Subbasin", and later goes on to say "…the Subbasin does not likely contain GDEs or interconnected surface water". Section 354.16 of the California Code of Regulations states that "each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes…GDEs". Just because GDEs are sparse and / or cover small areas does not make them insignificant. Many rare and protected species reside in GDEs since they are very unique ecosystems. **Please provide further information on the analysis of GDEs and westside streams, including citing field studies or modeling studies that show the hydrologic nature of these streams. Specifically indicate 1) which streams and GDE polygons were excluded, 2) identify any data gaps, and 3) ensure that GDE polygons are retained until data gaps are reconciled.**

Checklist Items 16 to 20, Describing GDEs (23 CCR §354.16) **1-14**

[Section 2.2.4.4.5 Groundwater Dependent Ecosystems (p. 2-44)]

- **Please provide information on the historical or current groundwater conditions near the GDEs or the ecological conditions present**. Refer to GDE Pulse (https://gde.codefornature.org; See Attachment E of this letter for more details) or any other locally available data (e.g., leaf area index, evapotranspiration or other data) to describe depth to groundwater trends in and around GDE areas, as well as trends in plant growth (e.g., NDVI) and plant moisture (e.g., NDMI). Below is a screenshot example of data available in GDE Pulse for NC dataset polygons found in the Westlands Water District.



- **Please provide an ecological inventory (see Appendix III, Worksheet 2 of the GDE Guidance) for all potential GDEs that includes vegetation or habitat types and rank the GDEs as having a high, moderate or low value. Explain how each rank was characterized.**
- **Please identify whether any endangered or threatened freshwater species of animals and plants, or areas with critical habitat were found in or near any of the GDEs since some organisms rely on uplands and wetlands during different stages of their lifecycle**. Resources for this include the list of freshwater species located in the Subbasin that can be found in Attachment C of this letter, the Critical Species Lookbook, and CDFW's CNDDB database.

<u>Checklist Items 21 and 22 – Water Budget (23 CCR §354.18)</u> 1-15

[Section 2.3.4 Water Budget Estimation (pp. 2-46 to 2-55)]

- Evapotranspiration is included as an outflow category in the land surface budget; however, it is not split between types of evapotranspiration. **Please separate this term by land-use type (for example: agricultural, municipal and domestic, and natural [i.e., native and riparian vegetation]).**
- Depending on the results of an updated review of GDEs, groundwater outflow to ET should be identified as a groundwater budget component. **Since potential GDEs (including wetlands, riparian vegetation, phreatophytes and other communities) are beneficial users of groundwater in the Westlands GSP area, it is appropriate to include them in these calculations.**

<u>Checklist Item 23-26 Sustainability Goal (23 CCR §354.24</u>) 1-16

[Section 3.1 Sustainability Goal (p. 3-4)]

- The Sustainability Goal states that "The goal of this GSP is to develop projects and management actions that result in the sustainable management of the groundwater resources of the Subbasin for long-term community, financial, and environmental benefits of residents and business in the Subbasin." The overall theme is to protect groundwater resources for developed water users. **Please expand the theme to include the environmental beneficial uses and users of groundwater.**
- The Goal Description states that environmental benefits were considered when establishing the minimum threshold for groundwater level; however, the criteria used was not included in the narrative. **Please update this section to provide detail on the environmental benefits to the GSP.**
- **Since GDEs and ISWs may be present in the Subbasin (please see comments under Checklist Items 16-20) they should be recognized as beneficial users of groundwater and should be included in the Sustainability Goal. In addition, a statement about any intention to address pre-SGMA impacts should be included.**
- The GSP states that there is no ISW connectivity along the westside creeks; however, there isn't any quantitative data provided, and / or information to support this finding. **Please include ISWs in the Sustainability Goal until sufficient data is available to conclude the status of ISWs.**
- GDEs are dependent, in part, on suitable water quality; however, the GSP only considers water quality for irrigation and domestic use. **Given that there are potential GDEs in the Subbasin, and they may be affected by water quality they should be included in the Sustainability Goal and addressed in the Water Quality section.**

<u>Checklist Item 26 – Measurable Objectives (23 CCR §354.30</u>) **1-17**

[Section 3.2.1 Measurable Objectives for Chronic Lowering of Water Levels (pp. 3-5 to 3-9)]

- This Measurable Objective does not consider GDEs. **Please include GDEs (see comments under checklist items 16-20) in this section and whether the measurable objectives and interim milestones will help achieve the sustainability goal as it pertains to the environment.**

[Section 3.2.4 Measurable Objectives for Water Quality (p. 3-14)] **1-18**

- This Measurable Objective does not consider the water quality needs of GDEs. **Please consider impacts from degraded water quality on ecological communities within GDEs**.

[Section 3.2.5 Measurable Objectives for ISWs Systems (3-17)] **1-19**

- This GSP states that there are no ISWs along the westside streams; however, this conclusion was based on well levels that are not reasonably close to the drainages. In addition, there is no supporting data and information that demonstrates the groundwater in the drainages is not supporting ISWs. **Please modify this section of the GSP to include a statement that includes the potential for ISWs,**

pending the characterization of the Shallow Zone and analysis of monitoring data or monitoring from additional wells to be installed in the future.

[Section 3.2.1.4 Impact of Selected Measurable Objectives on Adjacent Basins (p. 3-10)] **1-20**

- The GSP states that "Groundwater model results indicate that the average groundwater levels reflected in the MO will result in greatly reduced net subsurface inflow to the Plan area from surrounding subbasins compared to historic net subsurface inflow. Therefore, the projects and management actions implemented for this GSP are expected to benefit adjacent subbasins and not hinder the ability of adjacent subbasins to be sustainable". **Please explain how the measurable objectives will benefit adjacent subbasins and not hinder the ability of adjacent subbasins to be sustainable. What are the mechanisms for this benefit?**

[Section 3.2.4.1 Description of Measurable Objectives (for Water Quality) (p. 3-14)] **1-21**

- There is only one TDS well shown in Figure 3-5 for monitoring the Upper Aquifer, and it is located at the very southernmost tip of the GSP area. **Please explain how this one well will provide a representative estimation of TDS monitoring over the entire area and if there are data gaps, then please recognize any data gaps and state how they will be managed. If other monitoring wells will be used to manage TDS, then please state that.**

[Section 3.2.5.1 Description of Measurable Objectives and Section 3.3 Minimum Thresholds (for Interconnected Surface Waters) (pp. 3-17 to 3-18)] **1-22**

- Sweeping statements, such as "interconnected surface water does not exist in the Subbasin and therefore no minimum objectives were developed for this sustainability indicator. If in the future data from a groundwater level monitoring indicate that surface water from the ephemeral streams in the Subbasin and groundwater are interconnected, minimum thresholds and measurable objectives will be developed" are dismissive of ISWs and should be identified as data gaps. There is not enough evidence to make statements like these. Many of the wells are screened deeper and nested wells have not been installed to inform how shallow groundwater interacts with potential ISWs. **Please include all potential ISWs in the analysis and develop measurable objectives and minimum thresholds for these, to be managed until data gaps prove they are not interconnected.**

<u>Checklist Item 27-29 – Minimum Thresholds (23 CCR §354.28</u>) **1-23**

[Sections 3.3.1 Minimum Thresholds for Chronic Lowering of Groundwater Levels (p. 3-19)]

- The plan states that "Chronic lowering of groundwater levels in the Subbasin cause significant and unreasonable declines if they are sufficient in magnitude to lower the rate of production of pre-existing groundwater wells below that necessary to meet the minimum required to support beneficial use(s) where alternative means of obtaining sufficient water resources are not technically or financially feasible". The minimum threshold completely disregards environmental beneficial users, such as

ISWs or GDEs. **Although there are many data gaps associated with ISWs and GDEs, please address 1) how potential ISWs and GDEs would be affected by further lowering of groundwater levels, 2) how these beneficial users will be protected / managed in the interim until data gaps are filled, and 3) what measures will be employed to protect GDEs and ISWs that are confirmed after data gaps are filled.**

[Section 3.3.1.5 Effects of the Beneficial Uses and Users of Groundwater (p. 3-22)] **1-24**

- Effects to beneficial uses and users is focused on well capacity, pumping costs, extraction, and impacts from subsidence on infrastructure. There is no mention about potential impacts to GDEs or ISWs that could be affected by lowering of the Shallow Zone as affected by the Upper Aquifer since a continuity / discontinuity between the two is a data gap. **Please include the potential effects on ISWs and GDEs as beneficial users in this section.**

[Section 3.3.5 Minimum Thresholds for Water Quality (p. 3-27)] **1-25**

- Although agricultural water quality concerns were articulated, similar concerns were not identified for environmental users. Degradation of water quality can impact terrestrial and aquatic wildlife that live in or near these ecosystems during at least part of the year even if the water is not yet a concern from an agricultural standpoint. **Please include a discussion about GDEs and water quality and whether the minimum thresholds and interim milestones will help achieve sustainability for environmental users.**

[Sections 3.3.5.5 Effects of the Beneficial Uses and Users of Groundwater (p. 3-31)] **1-26**

- This section acknowledges the effects of the beneficial uses of groundwater as it relates to agriculture, urban and domestic uses. **Please add a statement to acknowledge how environmental uses and users would be affected by degradation of groundwater quality.**

[Sections 3.3.6 Minimum Thresholds for Interconnected Groundwater Surface Waters (p. 3-31)] **1-27**

- The GSP states that ISWs do not exist within the Westside Subbasin. **Please modify this section of the GSP to 1) identify possible ISWs, and 2) include a statement that a data gap exists related to the interconnectedness of the Shallow Zone with respect to possible ISWs.**

<u>Checklist Item 30-36 – Undesirable Results (23 CCR §354.26</u>) **1-28**

[Section 3.4.1.1 Undesirable Results (for chronic lowering of groundwater levels) (p. 3-36 to 3-37)]

- This section only describes undesirable results relating to human beneficial uses of groundwater and neglects environmental beneficial uses / users that could be adversely affected by chronic groundwater level decline. **Please add "possible adverse impacts to potential GDEs and ISWs" to the list of potential undesirable results.**

- The GDE Pulse web application developed by TNC provides easy access to 35 years of satellite data to view trends of vegetation metrics, groundwater depth (where available), and precipitation data. This satellite imagery can be used to observe trends for NC dataset polygons within and near the GSA. Over the past 10 years (2009-2018), some NC dataset vegetation polygons have experienced adverse impacts to vegetation growth and moisture. An example screen shot of GDEs near Huron, California from the GDE Pulse tool is presented under Checklist items 11-15 above.

    - **For each identifiable GDE unit with supporting hydrological datasets please include the following:**
        - Plot and provide hydrological datasets for each GDE.
        - Define the baseline period in the hydrologic data.
        - Classify GDE units as having high, moderate, or low susceptibility to changes in groundwater.
        - Explore cause-and-effect relationships between groundwater changes and GDEs.

    - **For each identifiable GDE unit without supporting hydrological datasets please describe data gaps and / or insufficiencies.**

    - **Compile and synthesize biological data for each GDE unit by:**
        - Characterizing biological resources for each GDE unit, and when possible provide baseline conditions for assessment of trends and variability.
        - Describing data gaps / insufficiencies.

    - **Describe possible effects on potential ISWs, GDEs, land uses, and property interests, including:**
        - Cause-and-effect relationships between potential ISWs and GDEs with groundwater conditions.
        - Impacts to potential ISWs and GDEs that are considered to be "significant and unreasonable".
        - Report known hydrological thresholds or triggers (e.g., instream flow criteria, groundwater depths, water quality parameters) for significant impacts to relevant species or ecological communities.
        - Land uses should include recreational uses (e.g., fishing/hunting, hiking, boating).
        - Property interests should include and consider privately and publicly protected conservation lands and opens spaces, including wildlife refuges, parks, and natural preserves.

[Section 3.4.1.4 Undesirable Results (for degraded groundwater quality) (p. 3-37)] **1-29**

- Section 2.2.2.2 Water Quality (p. 2-36) discusses water quality with respect to agricultural and municipal use but does not include metrics for GDEs and ISWs. **Please modify this section to specifically address how degraded water quality could affect the vegetative portion of GDEs and ISWs. Although Se and As are mentioned in this section please consider adding a statement that over-pumping and dewatering of aquitards has been known to degrade water quality in San Joaquin Valley aquifers.** The following is a link to a paper by Smith, Knight and Fendorf (2018) titled "Overpumping leads to California groundwater arsenic threat": https://www.nature.com/articles/s41467-018-04475-3

[Sections 3.4.1.5 Undesirable Results (for depletion of interconnected surface water) (p 3-38)] **1-30**

- The GSP states that there are no ISWs; however, there are no monitoring data and information to support this statement. Specifically, Table 3-1 and 3-12 list depletion of ISWs as "Not Applicable" as an Undesirable Result. This is a data gap that needs to be identified and rectified by employing a monitoring network to verify the status of ISWs prior to complete dismissal of ISWs from the GSP. **Please modify this section of the GSP to include a statement that 1) there are potential ISWs, 2) there will be no increase in depletions of potential ISWs, 3) and the presence or absence of ISWs will be verified with monitoring wells screened at the appropriate depth.**

1-31

<u>Checklist Item 37-46 – Undesirable Results (23 CCR §354.26)</u>

- Biological data should be compiled and synthesized for each GDE unit. **Based on the potential for GDEs in the Subbasin please include:**
  - Characterization of biological resources for each GDE unit, and when possible provide baseline conditions for assessment of trends and variability.
  - A description of data gaps / insufficiencies.
  - Stated plans to reconcile data gaps in the monitoring network.
- **Describe the following potential effects on GDEs, land uses and property interests:**
  - Cause-and-effect relationships between GDE and groundwater conditions.
  - Impacts to GDEs that are considered to be "significant and unreasonable".
  - Known hydrological thresholds or triggers (e.g., instream flow criteria, groundwater depths, water quality parameters) for significant impacts to relevant species or ecological communities.
  - Land uses include and consider recreational uses (e.g., fishing/hunting, hiking, boating).
  - Property interests include and consider privately and publicly protected conservation lands and opens spaces, including wildlife refuges, parks, and natural preserves.

<u>Checklist Items 47-49 – Monitoring Network (23 CCR §354.34)</u> **1-32**

[Section 3.3.1.1 Description of Minimum Threshold (p. 3-19)]

adversely affected by chronic groundwater level decline. δ**ssible**
adverse impacts to potential GDEs and ISWs
undesirable results.

The GDE Pulse web application developed by TNC provides easy access to 35 years of satellite data to view trends of vegetation metrics, groundwater depth (where available), and precipitation data. This satellite imagery can be used to observe trends for NC dataset polygons within and near the GSA. Over the past 10 years (2009-2018), some NC dataset vegetation polygons have experienced adverse impacts to vegetation growth and moisture. An example screen shot of GDEs near Huron, California from the GDE Pulse tool is presented under Checklist items 11-15 above.

- **For each identifiable GDE unit with supporting hydrological datasets please include the following:**
  - É Plot and provide hydrological datasets for each GDE.
  - É Define the baseline period in the hydrologic data.
  - É Classify GDE units as having high, moderate, or low susceptibility to changes in groundwater.
  - É Explore cause-and-effect relationships between groundwater changes and GDEs.

- **For each identifiable GDE unit without supporting hydrological datasets please describe data gaps and / or insufficiencies.**

- **Compile and synthesize biological data for each GDE unit by:**
  - É Characterizing biological resources for each GDE unit, and when possible provide baseline conditions for assessment of trends and variability.
  - É Describing data gaps / insufficiencies.

- **Describe possible effects on potential ISWs, GDEs, land uses, and property interests, including:**
  - É Cause-and-effect relationships between potential ISWs and GDEs with groundwater conditions.
  - É Impacts to potential ISWs and GDEs that are considered to be ≥VLJQLILFDQW DQG XQUHDVRQDEOH¥
  - É Report known hydrological thresholds or triggers (e.g., instream flow criteria, groundwater depths, water quality parameters) for significant impacts to relevant species or ecological communities.
  - É Land uses should include recreational uses (e.g., fishing/hunting, hiking, boating).
  - É Property interests should include and consider privately and publicly protected conservation lands and opens spaces, including wildlife refuges, parks, and natural preserves.

[Section 3.4.1.4 Undesirable Results (for degraded groundwater quality) (p. 3-37)]

ISWs or GDEs. **Although there are many data gaps associated with ISWs and GDEs, please address 1) how potential ISWs and GDEs would be affected by further lowering of groundwater levels, 2) how these beneficial users will be protected / managed in the interim until data gaps are filled, and 3) what measures will be employed to protect GDEs and ISWs that are confirmed after data gaps are filled.**

[Section 3.3.1.5 Effects of the Beneficial Uses and Users of Groundwater (p. 3-22)] 1-33

- Effects to beneficial uses and users is focused on well capacity, pumping costs, extraction, and impacts from subsidence on infrastructure. There is no mention about potential impacts to GDEs or ISWs that could be affected by lowering of the Shallow Zone as affected by the Upper Aquifer since a continuity / discontinuity between the two is a data gap. **Please include the potential effects on ISWs and GDEs as beneficial users in this section.**

[Section 3.3.5 Minimum Thresholds for Water Quality (p. 3-27)] 1-34

- Although agricultural water quality concerns were articulated, similar concerns were not identified for environmental users. Degradation of water quality can impact terrestrial and aquatic wildlife that live in or near these ecosystems during at least part of the year even if the water is not yet a concern from an agricultural standpoint. **Please include a discussion about GDEs and water quality and whether the minimum thresholds and interim milestones will help achieve sustainability for environmental users.**

1-35

[Sections 3.3.5.5 Effects of the Beneficial Uses and Users of Groundwater (p. 3-31)]

- This section acknowledges the effects of the beneficial uses of groundwater as it relates to agriculture, urban and domestic uses. **Please add a statement to acknowledge how environmental uses and users would be affected by degradation of groundwater quality.**

[Sections 3.3.6 Minimum Thresholds for Interconnected Groundwater Surface Waters (p. 3-31)] 1-36

- The GSP states that ISWs do not exist within the Westside Subbasin. **Please modify this section of the GSP to 1) identify possible ISWs, and 2) include a statement that a data gap exists related to the interconnectedness of the Shallow Zone with respect to possible ISWs.**

<u>Checklist Item 30-36 – Undesirable Results (23 CCR §354.26)</u>

[Section 3.4.1.1 Undesirable Results (for chronic lowering of groundwater levels) (p. 3-36 to 3-37)] 1-37

- This section only describes undesirable results relating to human beneficial uses of groundwater and neglects environmental beneficial uses / users that could be address water quantity and quality as well as providing environmental benefits or benefits to disadvantaged communities.

Attachment C

Freshwater Species Located in the Westside Subbasin

To assist in identifying the beneficial users of surface water necessary to assess the undesirable result "depletion of interconnected surface waters", Attachment C provides a list of freshwater species located in the Westside Subbasin. To produce the freshwater species list, we used ArcGIS to select features within the California Freshwater Species Database version 2.0.9 within the GSA's boundary. This database contains information on ~4,000 vertebrates, macroinvertebrates and vascular plants that depend on fresh water for at least one stage of their life cycle. The methods used to compile the California Freshwater Species Database can be found in Howard et al. 2015[5]. The spatial database contains locality observations and/or distribution information from ~400 data sources. The database is housed in the California Department of Fish and Wildlife's BIOS[6] as well as on TNC's science website[7].

Scientific Name	Common Name	Legally Protected Species		
		Federal	State	Other
BIRDS				
Actitis macularius	Spotted Sandpiper			
Aechmophorus clarkii	Clark's Grebe			
Aechmophorus occidentalis	Western Grebe			
Aix sponsa	Wood Duck			
Anas acuta	Northern Pintail			
Anas americana	American Wigeon			
Anas clypeata	Northern Shoveler			
Anas crecca	Green-winged Teal			
Anas cyanoptera	Cinnamon Teal			
Anas discors	Blue-winged Teal			
Anas platyrhynchos	Mallard			
Anas strepera	Gadwall			
Anser albifrons	Greater White-fronted Goose			
Ardea alba	Great Egret			
Ardea herodias	Great Blue Heron			
Aythya affinis	Lesser Scaup			
Aythya collaris	Ring-necked Duck			
Aythya marila	Greater Scaup			
Aythya valisineria	Canvasback		SSC	
Botaurus lentiginosus	American Bittern			
Bucephala albeola	Bufflehead			

[5] Howard, J.K. et al. 2015. Patterns of Freshwater Species Richness, Endemism, and Vulnerability in California. PLoSONE, 11(7). Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0130710
[6] California Department of Fish and Wildlife BIOS: https://www.wildlife.ca.gov/data/BIOS
[7] Science for Conservation: https://www.scienceforconservation.org/products/california-freshwater-species-database

Scientific Name	Common Name	Legally Protected Species		
		Federal	State	Other
Bucephala clangula	Common Goldeneye			
Butorides virescens	Green Heron			
Calidris alpina	Dunlin			
Calidris mauri	Western Sandpiper			
Calidris minutilla	Least Sandpiper			
Chen caerulescens	Snow Goose			
Chen rossii	Ross's Goose			
Chroicocephalus philadelphia	Bonaparte's Gull			
Cinclus mexicanus	American Dipper			
Cistothorus palustris palustris	Marsh Wren			
Cygnus columbianus	Tundra Swan			
Egretta thula	Snowy Egret			
Fulica americana	American Coot			
Gallinago delicata	Wilson's Snipe			
Geothlypis trichas trichas	Common Yellowthroat			
Himantopus mexicanus	Black-necked Stilt			
Limnodromus scolopaceus	Long-billed Dowitcher			
Lophodytes cucullatus	Hooded Merganser			
Megaceryle alcyon	Belted Kingfisher			
Mergus merganser	Common Merganser			
Mergus serrator	Red-breasted Merganser			
Numenius americanus	Long-billed Curlew			
Numenius phaeopus	Whimbrel			
Nycticorax nycticorax	Black-crowned Night-Heron			
Oxyura jamaicensis	Ruddy Duck			
Phalacrocorax auritus	Double-crested Cormorant			
Pipilo aberti	Abert's Towhee			
Plegadis chihi	White-faced Ibis		Watch list	
Pluvialis squatarola	Black-bellied Plover			
Podiceps nigricollis	Eared Grebe			

Scientific Name	Common Name	Legally Protected Species		
		Federal	State	Other
Podilymbus podiceps	Pied-billed Grebe			
Porzana carolina	Sora			
Rallus limicola	Virginia Rail			
Recurvirostra americana	American Avocet			
Riparia riparia	Bank Swallow		Threatened	
Rynchops niger	Black Skimmer			
Tachycineta bicolor	Tree Swallow			
Tringa melanoleuca	Greater Yellowlegs			
Tringa semipalmata	Willet			
Tringa solitaria	Solitary Sandpiper			
Vireo bellii	Bell's Vireo			
Laterallus jamaicensis coturniculus	California Black Rail	BCC	Threatened	BLM
Empidonax traillii	Willow Flycatcher	BCC	Endangered	USFS
Haliaeetus leucocephalus	Bald Eagle	BCC	Endangered	USFS, BLM
Pelecanus erythrorhynchos	American White Pelican		SSC	BSSC - First priority
Piranga rubra	Summer Tanager		SSC	BSSC - First priority
Agelaius tricolor	Tricolored Blackbird	BCC	SSC	BSSC - First priority, BLM
Histrionicus histrionicus	Harlequin Duck		SSC	BSSC - Second priority
Ixobrychus exilis hesperis	Western Least Bittern		SSC	BSSC - Second priority
Setophaga petechia	Yellow Warbler			BSSC - Second priority
Cypseloides niger	Black Swift	BCC	SSC	BSSC - Third priority
Geothlypis trichas sinuosa	Saltmarsh Common Yellowthroat	BCC	SSC	BSSC - Third priority
Xanthocephalus xanthocephalus	Yellow-headed Blackbird		SSC	BSSC - Third priority
CRUSTACEANS				
Caecidotea tomalensis	Tomales Isopod		SSC	
Hyalella spp.	Hyalella spp.			
FISHES				
Acipenser medirostris ssp. 1	Southern green sturgeon	Threatened	SSC	Endangered - Moyle 2013

Scientific Name	Common Name	Legally Protected Species		
		Federal	State	Other
Hypomesus pacificus	Delta smelt	Threatened	Endangered	Endangered - Moyle 2013
Oncorhynchus gorbuscha	Pink salmon		SSC	Endangered - Moyle 2013
Oncorhynchus keta	Chum salmon		SSC	Endangered - Moyle 2013
Oncorhynchus tshawytscha - CV late fall	Central Valley late fall Chinook salmon	SSC		Endangered - Moyle 2013
Acipenser medirostris ssp. 1	Southern green sturgeon	Threatened	SSC	Endangered - Moyle 2013
Catostomus occidentalis occidentalis	Sacramento sucker			Least Concern - Moyle 2013
Cottus aleuticus	Coastrange sculpin			Least Concern - Moyle 2013
Cottus asper ssp. 1	Prickly sculpin			Least Concern - Moyle 2013
Gasterosteus aculeatus aculeatus	Coastal threespine stickleback			Least Concern - Moyle 2013
Oncorhynchus mykiss irideus	Coastal rainbow trout			Least Concern - Moyle 2013
Orthodon microlepidotus	Sacramento blackfish			Least Concern - Moyle 2013
Ptychocheilus grandis	Sacramento pikeminnow			Least Concern - Moyle 2013
Hysterocarpus traskii traskii	Sacramento tule perch		SSC	Near-Threatened - Moyle 2013
Lampetra ayersi	River lamprey		SSC	Near-Threatened - Moyle 2013
Lavinia exilicauda exilicauda	Sacramento hitch		SSC	Near-Threatened - Moyle 2013
Lavinia symmetricus symmetricus	Central California roach		SSC	Near-Threatened - Moyle 2013
Entosphenus tridentata ssp. 1	Pacific lamprey		SSC	Near-Threatened - Moyle 2013, BLM, USFS
Lampetra richardsoni	Western brook lamprey			Near-Threatened - Moyle 2013, USFS
Mylopharodon conocephalus	Hardhead		SSC	Near-Threatened - Moyle 2013, USFS
Acipenser transmontanus	White sturgeon		SSC	Vulnerable - Moyle 2013
Eucyclogobius newberryi	Tidewater goby	Endangered	SSC	Vulnerable - Moyle 2013

Scientific Name	Common Name	Legally Protected Species		
		Federal	State	Other
Oncorhynchus mykiss - CCC winter	Central California coast winter steelhead	Threatened	SSC	Vulnerable - Moyle 2013
Oncorhynchus mykiss - CV	Central Valley steelhead	Threatened	SSC	Vulnerable - Moyle 2013
Oncorhynchus tshawytscha - CV fall	Central Valley fall Chinook salmon	SSC	SSC	Vulnerable - Moyle 2013
Oncorhynchus tshawytscha - CV spring	Central Valley spring Chinook salmon	Threatened	Threatened	Vulnerable - Moyle 2013
Oncorhynchus tshawytscha - CV winter	Central Valley winter Chinook salmon	Endangered	Endangered	Vulnerable - Moyle 2013
Pogonichthys macrolepidotus	Sacramento splittail		SSC	Vulnerable - Moyle 2013
Spirinchus thaleichthys	Longfin smelt	Candidate	Threatened	Vulnerable - Moyle 2013
Eucyclogobius newberryi	Tidewater goby	Endangered	SSC	Vulnerable - Moyle 2013
Spirinchus thaleichthys	Longfin smelt	Candidate	Threatened	Vulnerable - Moyle 2013
Anaxyrus boreas boreas	Boreal Toad			
Pseudacris regilla	Northern Pacific Chorus Frog			
Thamnophis sirtalis sirtalis	Common Gartersnake			
Thamnophis sirtalis tetrataenia	San Francisco Gartersnake	Endangered	Endangered	
Rana draytonii	California Red-legged Frog	Threatened	SSC	ARSSC
Taricha torosa	Coast Range Newt		SSC	ARSSC
Actinemys marmorata marmorata	Western Pond Turtle		SSC	ARSSC, BLM, USFS
Rana boylii	Foothill Yellow-legged Frog	Under Review in the Candidate or Petition Process	SSC	ARSSC, BLM, USFS
Thamnophis atratus atratus	Santa Cruz Gartersnake			Not on any status lists
Thamnophis elegans elegans	Mountain Gartersnake			Not on any status lists
Thamnophis elegans terrestris	Coast Gartersnake			Not on any status lists
INSECTS AND OTHER INVERTEBRATES				

Scientific Name	Common Name	Legally Protected Species		
		Federal	State	Other
Alotanypus spp.	Alotanypus spp.			
Apedilum spp.	Apedilum spp.			
Argia spp.	Argia spp.			
Argia vivida	Vivid Dancer			
Baetis tricaudatus	A Mayfly			
Brillia spp.	Brillia spp.			
Chironomus spp.	Chironomus spp.			
Conchapelopia spp.	Conchapelopia spp.			
Corixidae fam.	Corixidae fam.			
Cricotopus spp.	Cricotopus spp.			
Dicrotendipes spp.	Dicrotendipes spp.			
Enallagma carunculatum	Tule Bluet			
Enallagma civile	Familiar Bluet			
Ephydridae fam.	Ephydridae fam.			
Heterotrissocladius spp.	Heterotrissocladius spp.			
Ischnura cervula	Pacific Forktail			
Lestes stultus	Black Spreadwing			
Libellula pulchella	Twelve-spotted Skimmer			
Libellulidae fam.	Libellulidae fam.			
Metriocnemus spp.	Metriocnemus spp.			
Micropsectra spp.	Micropsectra spp.			
Pachydiplax longipennis	Blue Dasher			
Parametriocnemus spp.	Parametriocnemus spp.			
Paratanytarsus spp.	Paratanytarsus spp.			
Phaenopsectra spp.	Phaenopsectra spp.			
Plathemis lydia	Common Whitetail			
Polypedilum spp.	Polypedilum spp.			
Psectrotanypus spp.	Psectrotanypus spp.			
Pseudochironomus spp.	Pseudochironomus spp.			
Rhionaeschna californica	California Darner			
Simulium spp.	Simulium spp.			
Tanytarsus spp.	Tanytarsus spp.			
Zavrelimyia spp.	Zavrelimyia spp.			

Scientific Name	Common Name	Legally Protected Species		
		Federal	State	Other
Ischnura gemina	San Francisco Forktail		SSC	IUCN - Vulnerable
Tropisternus californicus				Not on any status lists
MAMMALS				
Lontra canadensis canadensis	North American River Otter			Not on any status lists
Ondatra zibethicus	Common Muskrat			Not on any status lists
MOLLUSKS				
Gonidea angulata	Western Ridged Mussel		SSC	
Hydrobiidae fam.	Hydrobiidae fam.			
Margaritifera falcata	Western Pearlshell		SSC	
Menetus spp.	Menetus spp.			
Physa spp.	Physa spp.			
Pisidium spp.	Pisidium spp.			
Anodonta californiensis	California Floater		SSC	USFS
PLANTS				
Alopecurus pratensis	NA			
Arundo donax	NA			
Carex obnupta	Slough Sedge			
Ceratophyllum demersum	Common Hornwort			
Cotula coronopifolia	NA			
Crassula aquatica	Water Pygmyweed			
Euthamia occidentalis	Western Fragrant Goldenrod			
Galium trifidum	Small Bedstraw			
Isolepis cernua	Low Bulrush			
Juncus effusus effusus	NA			
Juncus falcatus falcatus	Sickle-leaf Rush			
Juncus phaeocephalus phaeocephalus	Brown-head Rush			
Lemna minuta	Least Duckweed			
Mimulus guttatus	Common Large Monkeyflower			
Myriophyllum aquaticum	NA			
Phacelia distans	NA			