

**Intro to Summary Comments that follow by Bill Martin
on draft excerpts of future DWR regulations affecting geo heat pumps'
underground loops for thermal exchange
2-22-23**

The 79 pages that follow are a snapshot of activity by the Geothermal Heat Pump industry's efforts to engage with the CA Department of Water Resources over the past few years (and originally back to 2013 and their 1999 never-finalized draft regulations for what DWR insists are "water wells)." They insist on lumping four kinds of underground excavations into one set of regulations—each carrying the moniker "well."

1. Water wells
2. Geotechnical exploration wells (or bores)
3. Cathodic protection wells (or bores)
4. Geo heat pump underground heat exchange bores, both vertical and horizontal

A review of any dictionary will associate the word "well" with the extraction or infusion of liquid water. Numbers 2, 3, and 4 (above) have no such function. The purpose of our industry with #4 is to temporarily open an underground passage, insert resilient non-metallic piping as a closed loop, and to grout the passage fully to ensure contact between the formation and the pipe's surface. We pump potable or treated water through such closed loops to import low temperature heat to a geo heat pump (heating) or to export it (cooling).

Our industry has participated in a number of TACs (Technical Advisory Committees) with DWR staff. The relationship has been often "rocky" (no pun intended) because staff insists on classifying us as wells, and because we know that their (legitimate) worries over aquifer cross-contamination have never been cited as caused by our grouted heat exchange closed loops. When pressed for justification, their answer has been decidedly un-scientific, "...because we'd feel more comfortable, this way."

Because a comprehensive industry standard for North America already exists (ANSI/CSA/IGSHPA 448), since it covers all aspects of geo heat pump deployment and will likely be adopted in Europe—the DWR's efforts are duplicative. They unify four types of excavations that deserve separate regulatory treatment, they seem to be doing this for their own convenience, and their efforts may result in grouted vertical bore hole heat exchangers becoming prohibited, impossible, or uneconomic. Since geo heat pumps are the most efficient way to move heat in a state striving to lower its emissions, DWR's blunt methods will not improve climate change defensive measures.

Bill's Miscellaneous Comments **(IN RED)** in response to the definitions in the Technical Advisory Committee DWR Draft:

NOTE TO B74 TAC: Purple is used to highlight text added to the Water, Monitoring, and Cathodic Protection Well by the TAC Review Draft and to address Geothermal Heat Exchange Wells.

It's worth saying (again) that what are currently deemed as GHEWs by DWR should be in a separate category of regulation, even though many of the terms below are acceptable. We should slow or stop DWR soon enough to negotiate them toward a regulatory standard built around ANSI-IGSHPA-CSA 448, something that has already involved the industry and an increasing collection of jurisdictions who recognize it as a best practices bible with origins in many other codes and standards DWR seems oblivious of.

1. Definitions

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3. A well is considered abandoned, or permanently inactive, if it has not been used for one year and there is no intention for future use. Abandoned wells must be destroyed (decommissioned) immediately unless the owner demonstrates "intent for future use" and maintains the well in accordance with California Health & Safety Code Section 115700.

abandoned cathodic protection well A cathodic protection well is considered "abandoned" or permanently inactive under any of the following conditions:

- when its anodes are exhausted and cannot, or will not, be replaced;
- when the well has been replaced; when the well is no longer physically connected to a direct current source (such as a rectifier);
- when a well has not been energized for the past year;
- when current output requires a new well and the influence of the existing will not effectively contribute additional current to the structure.

accessory pipe Any tubular device installed as part of the well structure that is not the well casing or conductor casing (e.g., gravel fill pipe, sounding tube, video access tube, chemical injection tube).

active zone see conductive zone

admixture A material other than water, aggregate, and cement that is used as an ingredient in a cementitious material to modify its freshly

mixed, setting, or hardened properties and that is added to the batch before or during its mixing. (ASTM C125-03, modified)

annular space The space between any casing and the borehole wall, and the space between any two casings. The annular space is also referred to as the annulus.

anode (cathodic protection) An object, usually metallic, designed to corrode in place of the object it is designed to protect.

aquifer A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant quantities of groundwater to wells and springs. (DWR Bulletin 118: California's Groundwater, 2003)

bedding Bedding is material placed at the bottom of an excavation to provide uniform support for horizontal pipe components. Bedding typically consists of sand, gravel, or soil.

I fail to see how this addition improves the safety of water quality of near surface aquifers. Our industry is all about conducting loop direct contact with soil. Any inference that some amount of "settling" of horizontal loop geo heat exchange pipe is poised to leak is an assumption that ignores the flexible nature of our HDPE pipe. If any pipe risk related to bedding was more fully explained and tied to pipe expansion, weakening, fracture, etc., against ASTM test data—it would be more convincing.

bentonite A highly expansive colloidal clay used as primary component of drilling fluids, sealant, and as an admixture for cementitious sealing materials.

I would be more comfortable with this definition if it mentioned the word "grout" in the context of Tremie-pumped geothermal fill into boreholes. Drilling fluid is used in geo heat exchanger work, but grout is a larger part of what well-done geo shoots for in its vertical bores and like other construction terminology, "grout" is a permanent installation result—drilling mud is not.

This is another example of DWRs one standard for four types of underground bores that inappropriately lumps ours in with three others. Bentonite is a recipe-driven component of geo grout containing water, sand, and some additives for sealing contact and to maximize conductivity that we want. Geo's primary concern (direct conduction) is missing from this pedestrian definition.

bentonite slurry See slurry

borehole A hole drilled or bored into the earth.

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| casing | A tubular retaining structure which is installed in the well bore to maintain the well opening. Casing includes <u>well casing</u> , <u>conductor casing</u> , and <u>accessory pipe, including vent pipe used for cathodic protection wells</u> . |
| cathodic protection well | 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. (California Water Code Section 13711) |
| cement | An inorganic material as defined in ASTM C150, synonymous to portland cement and hydraulic cement. |
| cementitious material | An inorganic material or mixture of inorganic materials that sets and develops strength by chemical reaction with water by formation of hydrates and is capable of doing so under water. (ASTM C125-03) |
| centralizer | A fixture used to center casing(s) in a borehole or to separate casings from the borehole wall. |
| As long as this term targets casings only, I am okay with it. Apply it to geo loop spacing from the borehole wall and I object. | |
| concrete | A composite material that consists of <u>cement</u> , <u>aggregate</u> , and water. (ASTM C125-03, modified) |
| conductive backfill | Low resistivity material used to discharge current from the anodes to the soil, including but not limited to granular material, slurry material, and conductive concrete. |
| conductive concrete | Concrete with added carbonaceous material to lower its resistivity. |
| conductive zone | Zone of a cathodic protection well that discharges current. This zone consists of anodes surrounded by conductive backfill. |
| conductor casing | Conductor casing typically are large-diameter casings placed between the borehole wall and <u>well casing</u> to stabilize the upper formation while drilling and/or support the suspended weight of <u>well casing</u> and screen. (Handbook of Groundwater Development, Roscoe Moss Company, 1990, modified) |

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| confined groundwater | Confined groundwater is isolated from the atmosphere by geologic materials of low permeability and generally is present under pressures that are higher than atmospheric pressure. (Groundwater and Wells, 2007, modified) |
| confined aquifer | An aquifer overlain by a <u>confining layer</u> . (Applied Hydrogeology, Fetter, 1994) |
| confining layer | A bed or stratum of rock or sediment adjacent to and significantly less permeable than one or more aquifers. |
| corrosion | Deterioration of metallic objects by electrochemical reaction with the environment. (CP standard; see alternative definition in Terminology.xlsx) |
| crushed stone | The product resulting from the artificial crushing of rocks, boulders, or large cobblestones, substantially all faces of which have resulted from the crushing operation. (ASTM C125-03) |
| destruction | Destruction is the permanent, physical removal of a well from service through proper sealing according to these standards. The objective of destruction is to restore, as nearly as possible, the subsurface conditions that existed before the well was installed. Other terms commonly used in place of "destruction" are decommissioning, closure, and plugging. |
| dimension ratio | The DR is the outer diameter of a pipe or fitting divided by its minimum wall thickness. DR is used by the American Society for Testing and Materials (ASTM) in reference to high-density polyethylene (HDPE) pipe. |
| distribution line or distribution pipeline | Relatively small-diameter pipeline used extensively by municipal utilities to deliver product to individual customers. (enbridge.com, modified) |
| drilling fluid | A fluid (liquid or gas) used in drilling operations to remove cuttings from a borehole, clean and cool the drilling bit, reduce friction between the drill stem and the borehole wall, and, in some cases, to prevent caving or sloughing of the borehole. Drilling fluid returns contain cuttings and may contain pollutants. |
| embedment | Embedment is the material placed around horizontal pipe components. The embedment and the pipe act together as a pipe-soil structure to support and distribute external loads. |

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|--------------------------------------|--|
| excavation | An excavation is any artificial cut, cavity, trench, or depression in an earth surface that is formed by earth removal. See also "borehole". |
| fly ash | The finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gases from the combustion zone to the particle removal system. (ASTM C125-03) |
| formation | A body of rock or sediment sufficiently homogeneous or distinctive to be mappable as a unit. |
| freshly mixed | A composite material is regarded freshly mixed if it possesses enough of its original <u>workability</u> so that it can be placed and consolidated by the intended methods. (ASTM C125-03, modified) |
| gathering line or gathering pipeline | Pipeline that collects raw petroleum products from wellheads in a production field and moves it either to a processing plant or to an interconnection with the transmission system. (enbridge.com, modified) |

geothermal heat exchange well Any uncased artificial excavation, by any method, that uses the heat exchange capacity of the earth for heating and cooling, in which excavation the ambient ground temperature is 30 degrees Celsius (86 degrees Fahrenheit) or less, and which excavation uses a closed loop fluid system to prevent the discharge or escape of its fluid into surrounding aquifers or other geologic formations. Geothermal heat exchange wells include ground source heat pump wells. (California Water Code Section 13713)

I don't care that it's already in the water code, it shouldn't be there. We are geothermal heat exchange boreholes and will never be wells. Wells provide for the extraction of tangible mass as in water, gas, or crude oil. GHExs move Btus using a permanent tangible mass that circulates in a pumped loop (a world of difference).

| | |
|-------------|--|
| gravel | A natural, granular, mineral material of certain particle size greater than <u>sand</u> . (ASTM C125-03, modified) |
| gravel pack | Aggregate, typically sand and/or gravel, or other material (e.g., siliceous beads) placed in the annular space to stabilize the borehole wall and to prevent formation material from entering the well during pumping. |
| ground loop | A ground loop is a single loop of pipe installed in a borehole or excavation for circulating heat exchange fluid. Ground loops are typically U-shaped, but other shapes are used. Ground loops together |

with the “header assembly” form the “loop field,” described below and shown in Figure 1a.

groundwater That part of subsurface water which is in the zone of saturation, where water pressure is equal to or greater than atmospheric pressure.

header assembly The header assembly is a system of pipes (“headers”) and fittings that connect individual ground loops together and to the heat pump. The header assembly is typically installed in relatively shallow excavations approximately parallel to the ground surface. A header assembly is a component of a GHEW loop field as shown in Figure 1a.

local enforcing agency (LEA) The LEA is designated by duly authorized local, regional, or State government to administer and enforce laws and ordinances pertaining to the construction, maintenance, abandonment, and destruction of wells for the protection of water quality. In most California counties, the LEA is the county department of environmental health, but it can be another entity. The LEA is sometimes referred to as the “well permitting agency.”

loop field A loop field encompasses all subsurface piping that is part of a GHEW installation, including both ground loops and the header assembly, and supply and return lines (Figure 1a).

Get the W off of GHEW and make it GHEX for geothermal heat exchanger. GHEX perfectly describes the PURPOSE and FUNCTION of these installations.

loop field configuration Loop fields are designed and installed in a wide variety of configurations. These standards categorize loop field configurations into four types described below and shown in Figure 1a.

- **vertical.** Vertical loop fields are installed in one or more vertical boreholes, with loop piping in various configurations, including U-shaped or helix. Ground loops are connected to a header assembly of pipes installed in shallow excavations. Vertical borehole depths typically range from 75-500 feet.
- **inclined.** Inclined loop fields are commonly installed in an array of inclined boreholes that radiate out from a central excavation, which houses a header or manifold.
- **HDD.** HDD loop fields are installed via horizontal directional drilling (HDD) methods. HDD boreholes are typically drilled down at an incline until the design depth is reached, at which point the borehole extends horizontally for some distance, then inclines up to

daylight at the ground surface. The loop pipe is either pulled into the hole from the exit point or inserted (pushed) from the borehole entrance. HDD loop fields typically have a maximum depth of about 15-25 feet but may be deeper. (Note: Refrigerant-based systems are not installed with HDD methods.)

- excavated. Excavated loop fields are installed in excavations, with piping approximately parallel with the ground surface. Ground loops may be U-shaped or helix (sometimes referred to as “slinky”). Excavations are typically 3 to 10 feet deep, although they can be deeper.

loop-header connection The loop-header connection is the point of connection between a ground loop and the header assembly (Figure 1a).

I see no reason why the term describing the METHOD of heat fusing cannot be included here.

measured depth (MD) The length of the borehole measured along the borehole path from the ground surface.

monitoring well 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. (California Water Code Section 13712)

potable water Potable water meets drinking water standards in accordance with California Code of Regulations, Title 22, Chapter 15, Domestic Water Quality and Monitoring Regulations.

pozzolan A siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. (ASTM C125-03)

pressure grouting PLACEHOLDER PENDING PHASE 2 TAC FEEDBACK The placement of sealing material that involves the application of pressure to the sealing material to force it into void spaces where it would otherwise not flow. Pumping a sealing material through a tremie pipe against the hydrostatic pressure of the freshly placed material, while also requiring the application of pressure, is not considered pressure grouting.

pressure rating (PR) The PR is the "estimated maximum water pressure the pipe [or fitting] is capable of withstanding continuously with a high degree of certainty that failure of the pipe [or fitting] will not occur" (ASTM D-2837).

rectifier An electronic device that changes alternating current to direct current.

refrigerant-based system (GHEW) In a refrigerant-based system, a refrigerant is circulated through small diameter (typically ¼- to ⅝-inch outside diameter) copper tubing installed below ground surface for heat exchange purposes. In industry, refrigerant-based systems are referred to by other terms, including "direct exchange (DX)," "direct geotexchange heat pumps (DGX)," and "direct-expansion ground source heat pumps."

GHEX! And if the term refrigerant-based system is mentioned, a "system description" consisting at minimum of electrically-driven compressor, evaporator, and condenser ought to be stated.

sand A natural, granular, mineral material of certain particle size, smaller than gravel. (ASTM C125-03, modified)

setting (Cementitious material) The process, due to chemical reactions, occurring after the addition of water, that results in a gradual development of rigidity of a cementitious mixture. (ASTM C125-03, modified)

spacer A fixture used to maintain a certain distance between two or more casings.

slurry a semiliquid mixture of insoluble matter suspended in water

standard dimension ratio (SDR) The SDR is the outer diameter of a pipe or fitting divided by the minimum wall thickness. SDR is used by ASTM in reference to cross-linked polyethylene (PEX). ASTM F-876 specifies that, "For PEX-tubing, [SDR] is calculated by dividing the average outside diameter of the tubing in inches or in millimeters by the minimum wall thickness in inches or millimeters. If the wall thickness calculated by this formula is less than 0.070 in. (1.78 mm) it shall be arbitrarily increased to 0.070 in. except for sizes 5/16 in. and smaller, as specified in Table 1 [in ASTM F-876]. The SDR values shall be rounded to the nearest 0.5."

target aquifer That aquifer or water bearing zone that is screened to access groundwater.

transmission line or transmission pipeline Relatively large-diameter pipeline that moves product from a gathering, processing, or storage facility to a large-volume customer (e.g., a municipal utility), distribution system or other processing/storage facility. (enbridge.com, modified)

tremie A tubular device or pipe used to place materials in the annular space.

true vertical depth (TVD) Vertical measurement of a straight perpendicular line from a horizontal plane at the ground surface to the point of interest, independent of the path of the borehole. For vertical boreholes, the true vertical depth is equal to the measured depth.

unconfined aquifer An aquifer without a confining layer at the top. The top of an unconfined aquifer is the water table, which is the plane where groundwater pressure is equal to atmospheric pressure. (Groundwater Hydrology, 1978, modified)

vent pipe Piping, both perforated and unperforated, that is installed down hole to allow for gases to escape from an operating cathodic protection well.

water-based system (GHEW) In a water-based system, water is circulated through polyethylene piping installed below ground surface for heat exchange purposes.

GHEX! Just because closed loop water makes a round trip does not make this a well. Heat "exchange" is appropriately noted in this current definition.

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

This definition should also **exclude** geothermal heat pumps' heat exchangers that rest underground either vertically or in several options of horizontal. How can a horizontal closed loop heat exchanger be referred to as a WELL, as in GHEW? That's just nuts and has no connection to what is happening underground.

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| well casing | A tubular retaining structure installed in the well bore to maintain the well opening and protect any pumps or other equipment installed within. Well casing may be used with or without <u>conductor casing</u> . |
| workability | That property determining the effort required to manipulate a <u>freshly mixed</u> quantity of a composite material with minimum loss of homogeneity. (ASTM C125-03, modified) |

3. General Requirements

3.1. Applicability of these Standards

These standards apply to water wells, monitoring wells, cathodic protection wells (Appendix E Cathodic Protection Well Basics), and **geothermal heat exchange wells**, as defined in Water Code sections 13710 – 13713, regardless of whether they are oriented vertically or nonvertically.

Note to B74 TAC: Exact language addressing stormwater infiltration wells, or “drywells” as they are commonly called, that meet the definition of a water well is currently under development by DWR with input from the Water Boards. The proposed approach is as follows:

- Stormwater infiltration wells will continue to be permitted by LEAs on a case-by-case basis.
- Standards will reference the California Drywells Guidance Document (GeoSyntec, 2020), and any subsequent revisions for guidance on construction of stormwater infiltration wells.
- Standards will make clear that water well construction standards do not apply to stormwater infiltration wells.
- Destruction standards will apply to stormwater infiltration wells.

3.2. Variance Requests

If compliance with any of the requirements prescribed herein is infeasible for a particular well or location, the LEA may waive compliance and approve alternative requirements via variance.

Variance requests must be prepared in a letter or report format by a licensed California Professional Geologist or Engineer. Variance requests must include, at a minimum, the following information:

- A description of the requested variance – A clear and concise statement of the requested variance and the specific section or sections in the Well Standards for which a variance is requested or applies.
- Why the variance is being requested – The reason(s) why a variance is requested must be explained.

- A discussion on how, if approved, the requested variance will provide the same level of groundwater quality protection as intended by the Well Standards.
- Supporting information and analysis required by the LEA (Appendix A)
- Signature and stamp of submitting professional.

3.3. Change of Well Use

A well converted from one use to another must meet the minimum standards set forth herein.

3.4. Well Driller and Designer Qualifications

PLACEHOLDER TEXT. THIS SECTION WILL REFERENCE WATER CODE REQUIREMENTS REGARDING WELL DRILLER AND DESIGNER. QUALIFICATIONS.

3.5. Drilling Practices

Drilling practices should conform to industry best practices where they do not conflict with these standards. One source of industry standard practices for vertical and inclined drilling methods is the California Groundwater Association (CGA). HDD industry guidelines include the HDD Consortium's *Horizontal Directional Drilling Good Practices Guidelines* (Bennett and Ariaratnam, 2008) and ASTM F1962, *Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings*.

Request for TAC input: Are the provided references appropriate? If yes, are they sufficient? Are there other documents that should be referenced? As written, this section provides non-binding recommendations. Is this appropriate and useful?

3.6. Reports

PLACEHOLDER TEXT. THIS SECTION WILL REFERENCE WATER CODE REQUIREMENTS REGARDING WELL COMPLETION REPORTS.

3.7. Well Owner Responsibility

PLACEHOLDER TEXT. THIS SECTION WILL REFERENCE WATER CODE REQUIREMENTS REGARDING WELL OWNER RESPONSIBILITIES.

3.8. Referenced Standards and Guidelines

Where these standards, either directly or by reference, incorporate the requirements of other published standards or guidelines, such as those of ASTM International, Plastics Pipe Institute (PPI), National Sanitation Foundation International/American National Standards Institute (NSF/ANSI), American Society of Mechanical Engineers (ASME), or Manufacturers Standardization Society (MSS), the most recently published edition of the referenced standards apply. In addition, if there is a conflict between referenced standards or guidelines and these standards, these standards prevail.

3.9. Local, State, and Federal Law

PLACEHOLDER (all work must be done in accordance with applicable local, state, and federal law)

4. Site Planning

Site planning is necessary to aid in well design, identify problematic soil conditions, and determine the presence of pollutants or pollution sources. In some instances, existing information may be sufficient to characterize site conditions. Existing information may be obtained from various sources, such as well completion reports for nearby wells, public databases, and the LEA. Appendix B lists some statewide sources of the information to support site planning efforts described in this section.

4.1. Flooding

The location of the proposed well with respect to the floodplain of the 100-year flood, as defined by FEMA, must be determined. This determination affects applicability of surface construction features (Section 6.5 Surface Construction Features).

4.2. Surface Drainage

Within the constraints of the property or site, all reasonable efforts must be made to identify a well location that is not subject to inundation by overland flow, shallow concentrated flow, or ponding of surface water runoff. This includes surface water runoff and ponding in response to precipitation and anthropogenic activities (e.g., irrigation, discharges to land, washing, etc.).

If necessary, the area around the well must be built up so that drainage moves away from the well and the base is not subject to local ponding.

Surface drainage from areas near the well must be directed away from the well.

4.3. Well Location Map and Well Inventory

The proposed well must be depicted on a map or maps with sufficient information and at an appropriate scale to reliably find the well in the field and locate the well with respect to other mapped features. At a minimum, the well location map or maps must indicate:

- Proposed well(s) (latitude/longitude)
- North arrow
- Map scale
- Physical site address
- Nearest cross street(s)/intersection(s)
- Property outline (Assessor Parcel and Assessor Parcel Number, if applicable)

- Easement(s) and right-of-way(s), as applicable for well access
- Township, Range, and Section
- Various distances, as applicable to locate the well effectively and efficiently
- Existing wells on the parcel and any wells on adjacent parcels within 100 ft of proposed well location. This information may be provided by the LEA. (See “Well Inventory” below)
- Contaminated soil and groundwater sites located within 2,500 feet of a proposed well location, as identified by the State Water Resources Control Board’s GeoTracker and the California Department of Toxic Substances EnviroStor web-based applications, or similar applications.
- Surface water bodies
- Flood hazard designation (Section 4.1 Flooding)
- Local drainage/runoff patterns (Section 4.2 Surface Drainage)
- Point sources of pollution (Section 4.4 Well Location with Respect to Sources of Pollutants)
- Geologic hazards (Section 4.5 Geologic Hazards)

Well Inventory

Abandoned wells are a potential source of pollution and efforts must be taken to locate and address abandoned wells in the vicinity of a proposed well.

Well completion reports do not exist for all wells in California. Older wells may predate the WCR requirement and some WCRs contain inaccurate location information.

Therefore, a visual search must be conducted using aerial photography and/or field reconnaissance to locate nearby wells within 100 ft of the proposed well. For wells with a reduced surface seal, shorter than 50 ft (Section 6.4.2.2.1 Shallow Groundwater), the LEA may increase the search radius.

As a best practice, available well completion reports and construction information for nearby wells should be reviewed to inform the well design, including annular seal intervals (Section 6.4.2 Annular Seal Interval), and the selection of construction methods and materials.

4.4. Well Location with Respect to Sources of Pollutants

All **water wells, GHEWs, and cathodic protection wells** must be located an adequate distance, or “setback”, from identifiable sources of pollution. Setbacks in these standards

are limited to surface or near surface pollution sources. Such sources include but are not limited to those in Table 4-1.

Setbacks are measured along the shortest distance between the source of pollution and the borehole wall (**Figure-2**).

Minimum setbacks depend on the subsurface materials encountered by the well and the length of the surface seal. Table 4-1 distances assume a significant layer of unsaturated, unconsolidated sediment less permeable than sand is encountered between ground surface and groundwater. The well designer may determine that greater distances are needed depending upon soil type and the hydrogeology of the site. For instance, if a site has shallow groundwater (Section 6.4.2.2.1 Shallow Groundwater) or coarse soils, increased setbacks may be necessary.

For wells, including cathodic protection wells, with a surface seal meeting these standards (Section 6.4.2.2 Surface Seal), at least 50 ft in length, a reduction in Table 4-1 setbacks can be requested through a variance by providing evidence of a confining layer above the first screened interval or conductive zone that is greater than or equal to 30 ft thick.

Setbacks in Table 4-1 do not apply to monitoring wells and remediation extraction wells if regulatory requirements necessitate that these wells be located closer to existing known or potential sources of groundwater pollution. In such cases, a variance is not required.

Every reasonable effort must be made to not locate any well in a secondary containment area or in an area of a calculated spill level associated with **industrial facilities**. If there is no practical alternative location, special provisions regarding well openings must be followed (Section 6.5.1 Openings).

Table 4-1 Minimum Separation Distances

| Pollution Source | Minimum Separation Distance from Borehole or Excavation to Pollution Source (feet) |
|---|--|
| Pit privy | 50 |
| Any sewer (sanitary, industrial, or storm; main or lateral) | 50/25 ³ |
| Stormwater infiltration well | 100/50 ³ |

GHEW

50⁴/25⁵

Earthen-surfaced
animal housing (e.g.,
corral, confined
pasture)

Onsite wastewater
treatment system (i.e.,
septic tank, subsurface
sewage leaching field)

100, 150¹, 25³

Cesspool or seepage
pit

150/ 50³

Petroleum/chemical
storage tank
(subsurface)

100/50³

Petroleum/chemical
product non-
transmission line
(subsurface)

150/50³

Petroleum/chemical
product transmission
line (subsurface)

500/50³

Sewage, manure, or
waste percolation &
evaporation pond

500/50³

Sewage, manure, or
waste irrigation and
spreading area

500/50³

Storage & preparation
areas for pesticides/
fertilizers/chemicals
(Note 2)

500/50³

Solid waste disposal
site (CLASS 3)

500/50³

Solid waste disposal
site (CLASS 2)

2000/50³

Solid waste disposal
site (CLASS 1)

case-specific⁶

Regulated
contaminated sites

case-specific⁶

Notes for Table 4-1:

1. 100 feet from onsite wastewater treatment systems (e.g., septic tank, subsurface sewage leaching field); increase to 150 feet for public water system supply wells where the depth of effluent dispersal does not exceed 10 feet.
2. Anything less than fully enclosed with hard top flooring, walls, and roof.
3. GHEW
4. Community Supply Well
5. Domestic/Agricultural Supply Well
6. Information regarding land use restrictions/setback requirements for Class 1 Waste Disposal facilities and regulated contaminated sites may be obtained from agencies regulating the facility including, but not limited to, CalRecycle, Department of Toxic Substance Control (DTSC), and the State Water Resources Control Board.

6.5. Geologic Hazards

Within the constraints of the property or site, all reasonable efforts must be made to identify geologic hazards associated with slope instability and failure that are likely to cause failure/damage to the well structure. Such hazards include both slow (e.g., soil creep, subsidence, etc.) and rapid processes (e.g., landslides, rock falls, slumps, debris flows, etc.).

6.6. Subsurface Investigation

Drill cuttings or core samples from each borehole drilled or advanced, **or excavation**, must be consistently described in sufficient detail to characterize the nature of the materials encountered and to identify the boundaries between unlike materials, particularly as they relate to aquifer materials and confining layers. Minimum requirements are in Section 4.6.1 Sample Description.

Provision for nonvertical wells. For nonvertical wells drilled at angles less than 45 degrees to horizontal using techniques that do not allow the identification of depth-specific formation materials and material changes, such information must be generated in advance. This may include data collection efforts such as traditional vertical exploration.

Request for TAC Input: What minimum subsurface investigation is required/recommended for horizontal GHEWs?

6.6.1. Sample Description

At a minimum,

- Samples must be collected and inspected for every 10 feet of borehole advanced.
- Sample descriptions must be provided for each unique subsurface material encountered.

- Subsurface materials must be described using standard terminology consistent with the United Soil Classification System, ASTM D 2488 – Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), or the *Field Guide for Logging Water-Well Boreholes* (Hanna 2004), included in Appendix C.
 - Color should be described according to the Munsell Color Chart or the *Field Guide for Logging Water-Well Boreholes* (Hanna 2004) when sample is moist.
- Depths to tops and bottoms of identified materials must be referenced to ground surface. For nonvertical wells, both MD and TVD must be reported.

6.6.2. Other Observations or Investigative Tools

Other observations made, or testing completed, during the borehole drilling process that may be useful to identify and describe changes in subsurface materials or hydrogeologic conditions include, but are not limited to:

- Changes in drilling fluid viscosity
- Lost circulation conditions
- Flowing artesian conditions
- Gas or oil production
- Changes in drilling fluid temperature, EC, pH
- Drilling rig chatter or intervals of difficult drilling conditions
- Downhole geophysical surveys (E-Logs)
- Cone penetration testing (CPT) logs
- Cathodic protection resistance log

5. Materials

5.1. Concrete for Bases and Poured-in-Place Vaults

Concrete used for the construction of bases and poured-in-place vaults must be designed to withstand the forces resulting from the installation and operation of the well, including pumping equipment and site conditions (freeze/thaw, soil expansion) without cracking, or otherwise being damaged so that the base or vault can act as a barrier against infiltration of surface contaminants into the well structure. Additional standards for bases and vaults are discussed in Sections 6.5.2 Base and 6.5.3 Well Vaults.

5.2. Precast Well Vaults

Precast or pre-manufactured vaults and their lids or covers must be designed to withstand the forces resulting from the installation and operation of the well, including pumping equipment and site conditions (freeze/thaw, soil expansion) without cracking, or otherwise being damaged so that the vault can act as a barrier against infiltration of surface contaminants into the well structure. **Request for TAC input:** Are there ASTM or other standards for precast well vaults that should be cited here?

5.3. Casing

Sections 5.3.1 and 5.3.2 apply to water wells, monitoring wells, and cathodic protection wells.

Section 5.3.3 applies to GHEWs.

Well casing must be strong enough to resist the force imposed on it during installation and those forces which can normally be expected after installation. The selection of well casing should also consider the corrosive nature of fluids the well will be in contact with (e.g., high salinity water in coastal areas).

5.3.1. Steel Casing

All steel casing must have a certification mark verifying compliance with ANSI/NSF 61-2016 Drinking Water System Components – Health Effects.

5.3.1.1. Standard and Line Pipe

Standard and line steel pipe materials must meet one of the following specifications:

- API Standard 5L, "Specification for Line Pipe"
- API Standard 5LX, "Specification for High-Test Line Pipe"
- ASTM A53, "Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless"
- ASTM A120, "Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated (Galvanized) Welded and Seamless, for Ordinary Uses"
- ASTM A134, "Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (sizes NPS 16 and over)"
- ASTM A135, "Standard Specification for Electric-Resistance-Welded Steel Pipe"
- ASTM A139, "Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (sizes 4 inches and over)"
- ASTM A211, "Standard Specification for Spiral-Welded Steel or Iron Pipe"
- American Water Works Association (AWWA) C200, "AWWA Standard for Steel Water Pipe 6 Inches and Larger"

5.3.1.2. Structural Steel

Structural steel materials must meet one of the following ASTM standard specifications:

- ASTM A36, "Standard Specification for Carbon Structural Steel"
- ASTM A242, "Standard Specification for High Strength Low Alloy Structural Steel"
- ASTM A283, "Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality"
- ASTM A441, "Tentative Specification for High-Strength Low Alloy Structural Manganese Vanadium Steel"
- ASTM A1011/A1011M, "Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low Alloy with Improved Formability"

5.3.1.3. High Strength Carbon Steel

High-strength carbon steel materials must meet the following ASTM standard specification:

- ASTM A606/A606M, "Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance"

5.3.1.4. Stainless Steel

Stainless steel materials must meet one of the following ASTM standard specifications:

- ASTM A312/A312M, "Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes"
- ASTM A409/A409M, "Standard Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service"
- ASTM A778/A778M, "Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products"
- ASTM A928/A928M, "Standard Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal"

5.3.1.5. Casing for Public Water Supply Wells

In addition to Sections 5.3.1.1 to 5.3.1.4, for public water supply wells, the minimum thickness of steel casing must be at least as thick as outlined in AWWA Standard A100-06 as adopted by the California Code of Regulations for the casing diameter and the depth the casing is to be placed.

5.3.2. Plastic Casing

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

5.3.2.1. Thermoplastics

Thermoplastic well casing including PVC, ABS, and HDPE, must:

1. Be listed in the Plastics Pipe Institute Technical Report 4 (PPI TR-4), Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe, and
2. Meet the following ASTM standard specifications:
 - ASTM F480, "Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80"
 - ASTM D1527, "Standard Specification for Acrylonitrile- Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80"
 - ASTM D1785, "Standard Specification for (Poly Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120"
 - ASTM D2241, "Standard Specifications for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)"
 - ASTM F714 "Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter"

Thermoplastic well casing that may be subjected to significant impact stress during or after installation must meet or exceed the requirements for impact resistance classification set forth in 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.

5.3.2.2. Thermoset Plastics

Thermoset casing materials must meet one of the following standards:

- ASTM D2996, "Standard Specification for Filament Wound Reinforced Thermosetting Resin Pipe"
- ASTM D2997, "Standard Specification for Centrifugally Cast Reinforced Thermosetting Resin Pipe"

- ASTM D3517, "Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe"
- AWWA C950, "Standards for Glass-Fiber-Reinforced Thermosetting-Resin Pressure Pipe"

5.3.3. Casing and Fittings for GHEWs

Acceptable materials for water-based system loop field pipe and fittings are high-density polyethylene (HDPE) and cross-linked polyethylene (PEXa), as specified below. Use of metallic or polyvinyl chloride (PVC) pipe and fittings in water-based system loop fields is prohibited.

5.3.3.1. General Requirements for Water-Based System Pipe and Fittings

This section covers general requirements common to both HDPE and PEXa. Subsequent Sections, 5.3.3.2, "HDPE Pipe and Fittings," and 5.3.3.3, "PEXa Pipe and Fittings," include specific requirements for each type.

NSF certification. All HDPE and PEXa pipe and pipe fittings must be certified under NSF/ ANSI Standard 14, *Plastic Piping System Components and Related Materials*, or NSF/ANSI Standard 358-1, *Polyethylene Pipe and Fittings for Water-Based Ground-Source (Geothermal) Heat Pump Systems*.

Markings. Pipe and fittings must be permanently marked in accordance with ASTM and NSF/ANSI standards.

5.3.3.2. HDPE Pipe and Fittings

This section provides minimum specifications for HDPE pipe and fittings used in loop fields, including U-bends. General requirements under Section 5.3.3.1 also apply.

HDPE pipe and fitting materials designated as PE3608 and PE4710 (in accordance with ASTM F412, *Standard Terminology Relating to Plastic Pipe Systems*) meet the specifications below.

Working pressure. HDPE pipe and fittings must have a dimension ratio (DR) and a pressure rating (PR) sufficient to accommodate the maximum total working pressure at any point in the loop field accounting for velocity and inertial effects, surges, water hammer, shock waves, blockages, back pressures, temperature effects, elevation pressures, and pumping pressures. Pipe and fitting manufacturers should be consulted regarding to determine the PR at working temperatures above 73° F.

Hydrostatic design basis (HDB). HDPE pipe and fittings must have a minimum HDB of 1,600 pounds per square inch (psi) at 73° F per ASTM D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*.

Manufacturing specifications. The following are minimum manufacturing specifications for HDPE pipe and fittings used in loop fields, including U-bends.

Material. Pipe and pipe fitting material must be an HDPE compound with a minimum cell classification of PE345464C per ASTM D3350, *Standard Specification for Polyethylene Plastics Pipe and Fittings Materials*.

Pipe. HDPE pipe must be manufactured to the outside diameter, wall thickness, and tolerances specified in ASTM D3035, *Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter*, or in ASTM F714, *Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter*. The pipe must be listed in PPI TR-4, *Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe*.

Fittings. HDPE fittings must be manufactured according to the following specifications, as applicable:

- Butt-fusion fittings must meet dimensions and tolerances specified in ASTM D3261, *Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing*.
- Socket fusion fittings must meet tolerances specified in ASTM D2683, *Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing*.
- Electrofusion fittings must meet ASTM F1055, *Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing*.

In addition, all fittings used within a borehole must be joined to pipe inside in a controlled environment, such as a workshop or fabrication facility.

5.3.3.3. PEXa Pipe and Fittings

This section covers minimum specifications for PEXa components used in loop fields, including U-bends. General requirements under Section 5.3.3.1 also apply.

Materials meeting the minimum specifications below include PEXa 1006, 1008, 1306 and 1308, as defined in ASTM F876, *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*.

Working pressure. The standard dimension ratio (SDR) and pressure rating (PR) of PEXa pipe and fittings must be sufficient to accommodate the maximum total working pressure at any point in the loop field accounting for velocity and inertial effects, surges, water hammer, shock waves, blockages, back pressures, temperature effects, elevation pressures, and pumping pressures.

The SDR for PEXa is 9 per ASTM F876, *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*. According to ASTM F876, the PR of PEXa pipe and fittings decreases as the circulating fluid temperature increases. Pipe and fitting manufacturers should be consulted for working pressure reduction factors for operating temperatures above 73° F.

Hydrostatic design basis. PEXa pipe and fittings must have a minimum hydrostatic design basis of 1,360 psi at 73° F per ASTM D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*. PEXa materials meeting this requirement have a minimum PR of 160 psi for water at 73° F per ASTM F876, *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*. (Note: PEXa achieves the same PR as HDPE at a lower hydrostatic design basis.)

Manufacturing specifications. Following are minimum manufacturing specifications for PEXa pipes, U-bends, and fittings used in loop fields.

Material. PEXa pipe and fitting material must be manufactured by the high-pressure peroxide method and must conform to ASTM F876. PEXa material must have a minimum degree of cross-linking of 75 percent when tested in accordance with ASTM D2765, *Standard Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics, Method B*.

Pipe. PEXa pipe must be manufactured to the outside diameter, wall thickness, and tolerances specified in ASTM F876, *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*. The pipe must be listed in PPI TR-4, *Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe*.

Fittings. Fittings for PEXa systems, excluding U-bends (see below), must be manufactured according to the following specifications, as applicable:

- Polymer electrofusion fittings for PEXa pipe must conform to ASTM F1055, *Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing*. Electrofusion fittings must be HDPE manufactured in accordance with Section 5.3.3.2, “HDPE Pipe and Fittings.”
- Metal cold-expansion fittings with metal compression sleeves must conform to ASTM F2080, *Standard Specification for Cold-Expansion Fittings with Metal Compression-Sleeves for Cross-Linked Polyethylene (PEX) Pipe*, and must be approved for direct burial. These fittings must be used in conjunction with a manufacturer-approved corrosion protection covering.

U-bends. PEXa U-bends must be formed seamlessly within the ground loop according to hot or cold bending standards in ASTM F876, *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*. Hot bending enables a tighter bend radius than cold bending. Hot-bent U-bends must be factory-formed. Field-formed cold-bent U-bends are permitted.

5.3.3.4. General Requirements for Refrigerant-Based System Tubing and Fittings

This section covers minimum requirements for tubing and fittings used in refrigerant-based system loop fields.

Copper tubing and fitting materials meeting the specifications below include Type L and ACR, as identified in ASTM standards referenced below.

Working pressure. The maximum total working pressure of a refrigerant-based system loop field must not exceed the internal working pressure-temperature ratings of individual components (e.g. tubing, fittings, and joints) at the maximum operating temperature. Pressure-temperature ratings for each component are contained in the applicable standards, as referenced in ASME B31.5, *Code for Pressure Piping, Refrigeration Piping and Heat Transfer Components*. Copper joined by soldering or brazing requires adjusted pressure ratings. Tubing and fitting manufacturers should be consulted about pressure ratings and adjustment factors.

Manufacturing specifications. Following are the minimum manufacturing specifications for copper tubing and fittings used in refrigerant-based systems.

Tubing. Two types of copper tubing are approved for refrigerant-based systems:

- Type L copper tubing manufactured according to ASTM B88, *Standard Specification for Seamless Copper Water Tube*.
- ACR copper tubing meeting specifications of ASTM B280, *Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service*.

Fittings. Fittings for refrigerant-based system loop fields must meet the appropriate ASTM, ASME, and MSS standards, as specified in ASME B31.5, *Code for Pressure Piping, Refrigeration Piping and Heat Transfer Components*.

Corrosion Protection. Protective coatings approved by the tubing or fitting manufacturer may be used for supplemental corrosion protection.

Markings. Tubing and fittings must be permanently marked in accordance with the appropriate ASTM, ASME, or MSS standards

5.3.4. Concrete Casing

Concrete casing materials must meet one of the following standards:

- ASTM C14, "Standard Specifications for Concrete Sewer, Storm Drain, and Culvert Pipe"
- ASTM C76, "Standard Specifications for Reinforced Concrete Sewer, Storm Drain, and Culvert Pipe"
- AWWA C300, "AWWA Standard for Reinforced Concrete Pressure Pipe Steel Cylinder Type, for Water and Other Liquids"
- AWWA C301, "AWWA Standard for Prestressed Concrete Pressure Pipe Steel, Cylinder Type, for Water and Other Liquids"

5.3.5. Cathodic Protection Well Vent Pipe

Cathodic protection well vent pipe must be at least 2 inches in internal diameter to facilitate eventual well destruction. Perforations must be in the form of slots or holes for vent pipe in the conductive fill. The size of the holes or slots should be maximized to provide maximum grout penetration during future well destruction while at the same time considering the conductive backfill gradation to minimize the potential for conductive backfill entering and plugging the vent pipe.

5.4. Slip Joints

In areas where deep subsidence may occur (as, for example, portions of the San Joaquin Valley), provision must 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.

5.5. Centralizers and Spacers

Centralizers and spacers must be made of metal, plastic, or other non-degradable material. Wood is not allowed. Any metallic component of a centralizer or appurtenance used with metallic casing must consist of the same material and meet the same metallurgical specifications and standards as the metallic casing to reduce the potential for galvanic corrosion of the casing.

5.6. Gravel Pack

Aggregate placed in the annulus for the purpose of borehole/formation stabilization must be clean, washed, stable, non-toxic, non-leaching, and free of organic material and debris.

5.7. Conductive Backfill for Cathodic Protection Wells

The conductive backfill in which the anodes are emplaced must be stable, non-toxic, non-leaching, and free of organic material and debris. This includes coke (also known as coke breeze or calcined petroleum coke backfill). Conductive concrete used as a sealing material must comply with Section 5.8 Sealing Material Components, 5.8.4 Admixtures, and 5.9.2 Cementitious Sealing Materials.

5.8. Sealing Material Components

5.8.1. General Requirement

Except for water and aggregate, each sealing material component must comply with NSF/ANSI Standards 60 and/or 61. Alternatively, the “Concrete Site Mix Evaluation Method” described in Section 5.9.1 Performance Standard, Compatibility, and Mixing, may be used to verify that a cementitious sealing material is NSF/ANSI 61 compliant even if one or more of the individual components is not certified.

5.8.2. Water

The quality of water added to sealing material must be free of pollutants and must not adversely affect the sealing material's properties. Water used in cementitious sealing materials, should not exceed 2,000 milligrams per liter chloride and 1,500 mg/l sulfate. Adhere to sealing material manufacturer's specifications and applicable ASTM standards for water quality requirements.

5.8.3. Cement

Cement must meet the requirements of ASTM C150 "Standard Specification for Portland Cement."

5.8.4. Admixtures

Admixtures for cementitious materials must meet the requirements of ASTM C494 "Standard Specification for Chemical Admixtures for Concrete".

Fly Ash as defined by ASTM C618 "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete," may be used in concrete to replace up to 25% by weight of portland cement.

Request for TAC input: What is the maximum percent of cement that should be allowed to be replaced by fly ash, if used?

Hydrated lime may be added up to 10 percent of the volume of cement used to make the sealing mixture more fluid.

Bentonite may be added up to 6 percent by weight of cement used, to improve fluid characteristics of the sealing mixture and reduce the rate of heat generation during setting. Bentonite increases viscosity and should not be added to cementitious materials used in certain well destructions (Sections 9.2.2.1 Approved Sealing Materials (Mechanical Perforation) and 9.2.4.1 Approved Sealing Materials (Cement-Sealed Wells)).

Admixtures that are used to make conductive concrete must yield a product (i.e., conductive concrete) that is NSF/ANSI 61 compliant.

5.8.5. Aggregate

Aggregate must meet the specifications of ASTM C33 "Standard Specification for Concrete Aggregates" and of the sealing material manufacturer. The quality of aggregate must be compatible with other ingredients and must not adversely affect the sealing material's properties.

Sand properties can impact pumpability. Sand that is too fine can increase pumping pressures and viscosity. This may result in excess water being added to the pumped mix, increasing the hydraulic conductivity of emplaced sealing material. Sand that is too coarse can settle out of the mix and cause pumpability problems. Sand grain shape can

also impact viscosity and pumpability. Well-rounded sand is easier to pump than angular sand.

Sections 5.9.2 Cementitious Sealing Materials and 5.9.3 Bentonitic Sealing Materials include specific requirements for aggregates, such as gradation, for each approved sealing material.

5.8.6. Bentonite

Bentonite must be commercially prepared, powdered, granulated, pelletized, or chipped/crushed sodium bentonite.

5.9. Approved Sealing Materials

5.9.1. Performance Standard, Compatibility, and Mixing

Approved sealing materials for annular seals and well destruction must be mixed in accordance with the manufacturer's **or developer's** specifications to achieve a hydraulic conductivity of less than or equal to 1×10^{-7} cm/s as determined by ASTM D5084 "Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter". Sealing material components must conform to Section 5.8 Sealing Material Components and be thoroughly mixed to achieve uniform hydration and an effective, homogeneous seal. Approved sealing materials must be compatible with the buried components of the well system and the subsurface environment.

For cementitious materials, NSF/ANSI 60 and/or 61 compliance can be met through certification of individual components (Section 5.8.1 General Requirement), or alternatively, using the "Concrete Site Mix Evaluation Method" in accordance with the AWWA Waterworks Standards - Concrete Used for Drinking Water Systems, May 2015. The Concrete Site Mix Evaluation may be used to verify a cementitious sealing is NSF/ANSI 61 compliant even if one or more of the individual components is not certified, such as cement or fly ash. This method requires samples analysis of the hardened cementitious material to be analyzed by an ANSI-accredited laboratory to determine NSF/ANSI 61 compliance as follows: "Samples of the hardened concrete, with proper chains-of-custody are analyzed by an ANSI-accredited laboratory to determine if the mixture meets the requirements of the analytes provided under NSF/ANSI 61 Table 3.1 – Portland and Hydraulic Cements. There are additional analytes to be tested for under Portland and hydraulic cements as opposed to those listed for concrete in Table 3.1." (AWWA, 2015)

5.9.2. Cementitious Sealing Materials

5.9.2.1. Neat Cement

For Types I or II portland cement, one 94-pound sack of portland cement must be mixed with 5 to 6 gallons of water. Additional water may be required when admixtures are

used, but the resulting neat cement must not exceed hydraulic conductivity limits in Section 5.9.1 Performance Standard, Compatibility, and Mixing.

5.9.2.2. Sand Cement

Sand cement must be mixed at a ratio of not more than 188 pounds of fine aggregate to one 94-pound sack of portland cement (i.e., 2 parts fine aggregate to 1 part cement, by weight) and up to 6 gallons of water, where Type I or Type II portland cement is used.

More water may be required when admixtures are used, but the resulting sand cement must not exceed hydraulic conductivity limits in Section 5.8.1 Performance Standard, Compatibility, and Mixing.

Fine aggregate grading must conform to specifications set forth in ASTM C33 "Standard Specification for Concrete Aggregates" or Caltrans Standard Specifications Division XI Materials, Section 90 Concrete, for Fine Aggregate Gradation. In addition, for well sealing applications:

1. The greatest allowed particle size must pass the 3/8-inch sieve with not more than 5% of aggregate retained by the No. 4 sieve (3/16-inch).
2. The greatest allowed particle size must not exceed 1/5th the thickness of the seal.

2.1.1.1. Sand Cement for GHEWs (Mix 111)

Mix 111 must be mixed and placed in accordance with *Guidelines for Mixing and Placing Thermally Conductive Cementitious Grout (Mix 111)* (Allan 1999), included in Appendix (TBD).

2.1.1.4. Concrete

For purposes of these standards, "concrete" is used to refer to cementitious sealing material that has a larger percent of coarse aggregate than that allowed for sand cement (Section 5.8.5 Aggregate).

Concrete must be mixed at a ratio of not more than 188 pounds of aggregate to one 94-pound sack of portland cement (i.e., 2 parts aggregate to 1 part cement, by weight) and up to 6 gallons of water, where Type I or Type II portland cement is used.

More water may be required when admixtures are used, but the resulting concrete must not exceed hydraulic conductivity limits in Section 5.9.1 Performance Standard, Compatibility, and Mixing.

Aggregate grading may be coarser than specifications set forth in ASTM C33 "Standard Specification for Concrete Aggregates" or Caltrans Standard Specifications Division XI Materials, Section 90 Concrete, for Fine Aggregate Gradation. For well sealing applications:

1. The greatest allowed particle size must pass the 3/8-inch sieve and up to 100% of aggregate may be retained by the No. 4 sieve (3/16-inch).
2. The greatest allowed particle size must not exceed 1/5th the thickness of the seal.

Concrete for Destruction of Large Diameter Wells. For the destruction of wells with a diameter of 3 feet or more, the concrete mixture's greatest allowed aggregate particle size is 4 inches. Such concrete mixture cannot be placed via tremie pipe, and therefore, may only be placed above 30 ft TVD in accordance with Section 7.6.5 Method of Placement, "Freefall Exception".

1.3. Bentonitic Seals

Bentonite-based sealing materials must not be used in the following environments:

- Areas of high salinity (salt concentration) and/or high hardness (calcium and magnesium concentration) which can inhibit the hydration and performance of the seal.

Request for TAC input: Is there an upper concentration limit for chloride, calcium, magnesium, and total dissolved solids that should be included in the standards?

- Areas of pollution by organic chemicals, such as petroleum distillates and/or solvents.

Request for TAC input: Please advise on specific chemicals or groups of chemicals that inhibit bentonite hydration.

- Areas where the sealing materials could be subject to long-term desiccation, such as where the bentonite-based seal would be permanently above the water table.
- Areas or sealing intervals where highly unstable, unconsolidated material that could collapse and displace the sealing material.
- Sealing intervals of fractured rock.
- Areas where flowing water might erode the seal material.

1.3.1. High Solids Sand-Bentonite Slurry

High solids sand-bentonite slurry must use powdered bentonite and be mixed at a sand-to-bentonite ratio of 4:1 to 8:1, by dry weight. Solids content must range between 64% to 72% by dry weight of solids (sand and bentonite) to the total weight of the slurry (i.e., with water added). Sand properties must meet the sealing material manufacturer's specifications for grain shape and gradation, as applicable.

1.3.2. Non-Slurry Bentonite

Non-slurry bentonite must be granulated, pelletized, or chipped/crushed (*not* powdered). At the time of placement in the annular space, and before hydration occurs, the maximum dimension of individual granules, chips, or pellets must be no greater than one-fifth (1/5) the minimum radial thickness of the annular seal. Non-slurry bentonite may be coated to retard hydration.

1.4. GHEW Heat Exchange Fluids

Water Based Systems - The fluid circulated as the heat exchange medium in a water based system must be potable water. United States Pharmacopeia (USP) food-grade propylene glycol (Chemical Abstracts Service [CAS] Number 57-55-6) may be used as a freeze protection additive. Any corrosion inhibitors added to water-based systems must be approved in advance by the LEA and must meet NSF/ANSI Standard 60, *Drinking Water Treatment Chemicals – Health Effects* or NSF/ANSI Standard 61, *Drinking Water System Components – Health Effects*.

NOTE All other additives, including ethylene glycol, are strictly prohibited.

Refrigerant-Based Systems - Acceptable refrigerants for refrigerant-based systems are R-407C and R-410A and must comply with:

ANSI/ASHRAE, "Standard 34, Designation and Safety Classification of Refrigerant"

Other refrigerants may be used if they are approved by both the U.S. Environmental Protection Agency (EPA) and the California Environmental Protection Agency (CalEPA), and are acceptable to the SWRCB in terms of groundwater quality protection.

Lubricating oils used in refrigerant-based systems must be food grade.

1.5. Drilling Fluids

All drilling fluids and drilling fluid additives must meet the following requirements:

- Drilling fluids must be nontoxic and free of pollutants.
- All water used for drilling must be obtained from a source that will not result in chemical or biological contamination of groundwater.
- All drilling fluid additives in addition to water, including bentonite, polymers, lost circulation prevention materials, deflocculants, surfactants, lubricants, and hardness- (e.g. calcium carbonate) and pH-control additives (e.g. soda ash) must meet NSF/ANSI Standard 60, *Drinking Water Treatment Chemicals – Health Effects*, or NSF/ANSI 61, *Drinking Water System Components – Health Effects*, and must not result in groundwater pollution.
- Drilling fluid additives must be chemically compatible with casing materials.
- Drilling fluid additives must be chemically compatible with annular seal materials.

- Drilling fluids, spent drilling fluids, and cuttings must be contained in aboveground tubs, tanks, or lined pits at all time. Spent drilling fluids and cuttings must be handled and disposed of in accordance with State and local requirements.

6. Design

Section 6 Design applies to water wells, monitoring wells, cathodic protection wells, and geothermal heat exchange wells. Where needed, standards are provided for specific well types. In addition, the following sections, and associated subsections, are applicable to geothermal heat exchange wells:

- Section 6.3 GHEW Loop Field Design Elements
- Section 6.5.8 GHEW Pressure Relief Valve Installation
- Section 6.5.9.1 Underground Markers for GHEW
- Section 6.5.9.2 System Labels for GHEW

6.1. Designing for Eventual Destruction

The design of a well must facilitate its eventual destruction in accordance with these standards (Section 9 Destruction). Well designs that employ flexible tubing or very small diameter casing must include provisions that make successful destruction plausible.

6.2. Selection of Materials

Selection of materials (e.g., casing, fittings, annular seal, drilling fluids additives, heat exchange fluids/refrigerants) used in construction of wells must consider compatibility of those materials with each other and with the chemical environment (soil and groundwater conditions, pollutants) they are to be placed in.

Heat of Hydration. Heat of hydration must be considered in the selection of plastic casing to be used with cementitious annular sealing materials. Heat of hydration can damage or collapse the casing during construction. In addition to selection of plastic casing, other precautions to reduce adverse effects of heat of hydration include use of admixtures (Section 5.8.4 Admixtures), and circulation of water inside the casing during construction (Section 7.2 Casing Handling and Installation).

6.3. GHEW Loop Field Design Elements

Section 6.3 GHEW Loop Design Elements and subsections apply to GHEWs, only. The remainder of Section 6 Design also applies to GHEWs.

6.3.1. Minimum Depth of GHEWs

All elements of a GHEW loop field, including ground loops, headers, loop connectors, and building supply and return lines, must be at least three (3) feet below ground surface.

6.3.2. Sealing Materials for GHEWs

Water Based Systems. Only high solids sand-bentonite slurry (Section 5.9.3.1 High Solids Sand-Bentonite Slurry), non-slurry bentonite (Section 5.9.3.2 Non-Slurry Bentonite), and Mix 111 (Section 5.9.2.3 Sand Cement for GHEWs (Mix 111)) are approved materials for annular seals.

Refrigerant Based Systems. Mix 111 is the only approved annular seal material (Section 5.9.2.3 Sand Cement for GHEWs Mix 111).

6.3.3. Casing and Fittings for GHEWs

Water Based Systems. Only polyethylene (high-density polyethylene (HDPE) and cross-linked polyethylene (PEXa)) pipe and fittings may be used for water-based loop field systems.

Refrigerant Based Systems. Loop field systems using refrigerant must only use copper pipe and fittings.

Thermal expansion. Both HDPE and PEXa pipe and fittings lengthen significantly in response to increased temperature, and shorten in response to decreased temperature. HDPE and PEXa have a coefficient of longitudinal (axial) thermal expansion and contraction of approximately one (1) inch for each 10° Fahrenheit (F) of temperature change for each 100 feet of pipe (sometimes referred to as the “1/10/100 rule”).

Thermally-induced stresses, together with other stresses (such as hydraulic stresses), must not exceed the maximum allowable working stress of the pipe and fittings

Chemical resistance. Although polyethylene materials are generally resistant to chemical attack, they can be adversely affected by certain substances, such as aromatic and halogenated hydrocarbons, aromatic ketones, oxidizing agents, detergents, and alcohols. Use of HDPE and PEXa is prohibited where it may be chemically attacked by these or other compounds.

6.3.3.1. Joining of Pipe and Fittings for GHEWs

Field joining is permitted only for the header assembly. Any connections within a borehole must be joined inside in a controlled environment, such as a factory, workshop, or fabrication facility, according to pipe manufacturer’s instructions.

6.3.3.2. Working Pressure in GHEWs

The standard dimension ratio (SDR) and pressure rating (PR) of HDPE and PEXa pipe and fittings must be sufficient to accommodate the maximum total working pressure at any point in the loop field accounting for velocity and inertial effects, surges, water hammer, shock waves, blockages, back pressures, temperature effects, elevation pressures, and pumping pressures. Pipe and fitting manufacturers should be consulted regarding to determine the PR at working temperatures above 73° F. The maximum total working pressure of a refrigerant-based system loop field must not exceed the internal working pressure-temperature ratings of individual components (e.g. tubing, fittings,

and joints) at the maximum operating temperature. Copper joined by soldering or brazing requires adjusted pressure ratings. Tubing and fitting manufacturers should be consulted about pressure ratings and adjustment factors.

6.3.4. Corrosion Protection for Refrigerant-Based GHEWs

Cathodic protection is required for all refrigerant-based GHEWs.

Supplemental corrosion protection, such as an external protective polyethylene coating for copper tubing, is recommended. However, a protective coating is not an allowable substitute for cathodic protection because of the likelihood of damage to pipe coatings during installation into a borehole or excavation.

Cathodic protection systems must comply with ASME B31.1, *Code for Pressure Piping, Power Piping*, and cathodic protection wells must also comply with these standards.

It is strongly recommended that refrigerant-based systems are not placed in subsurface environments known to be corrosive to copper. Information on the corrosive effects of various subsurface conditions on copper is available from the Copper Development Association and NACE International (formerly the National Association of Corrosion Engineers).

6.4. Seals

6.4.1. Thickness of Annular Seals and Use of Centralizers and Spacers

Within the interval to be sealed, a minimum of two inches of sealing material must be maintained between each casing and the borehole wall, and between all casings (**Figure-3**). The well structure must be equipped with centralizers and/or spacers to accomplish this. Centralizers and/or spacers must be placed at least every 80 ft. *In the case of water and monitoring wells, centralizers and/or spacers must also be placed at the top and bottom of screened intervals. In the case of cathodic protection wells, centralizers and/or spacers must also be placed at the top and bottom of the conductive zone(s).* Centralizers and/or spacers must not interfere with the placement of sealing material.

Centralization with Hollow-stem Augers. Centralizers need not be used in cases where the well casing is centered in the borehole, while maintaining a minimum distance of two inches from the borehole wall, during well construction by use of removable guides, such as hollow-stem augers.

Centralization in Nonvertical Wells. For nonvertical monitoring wells and remediation extraction wells installed at angles less than 45 degrees to horizontal and drilled with technology that does not permit the effective use of centralizers (i.e., horizontal directional drilling), the casing must be centralized in the surface seal interval by supporting the casing under tension while sealing material is placed around the casing and allowed to set. Casing centralized in this manner will not achieve the same quality of

surface seal as with centralizers or removable guides, and therefore, this method is only permitted for wells constructed in first encountered groundwater and not completely penetrating a confining layer that separates shallow groundwater from deeper water per Sections 6.4.2.1 General Requirements and 6.4.2.2.1 Shallow Groundwater. Caution should be exercised when locating such a well with respect to sources of pollution and flooding (Section 4.4 Well Location with Respect to Sources of Pollutants and Section 4.1 Flooding). Such precautions include horizontal separation distances greater than those in Table 4-1.

6.4.2. Annular Seal Intervals

Annular seal intervals include the surface seal (Section 6.4.2.2 Surface Seal), formation seals (Section 6.4.2.4), and conductor casing seal (Section 6.4.2.3 Conductor Casing Seal). The transition seal (Section 6.4.3 Transition Interval and Transition Seal) is not part of the annular seal.

6.4.2.1. General Requirements

Water wells and monitoring wells. Annular space that is not opposite the target aquifer must be sealed with approved sealing materials (Section 5.9 Approved Sealing Materials). This excludes annular space immediately above and below the target aquifer(s), which is reasonably needed for the placement of (1) sand/gravel pack reserve (no greater than 50 feet in length) to support the well's functionality, and/or (2) transition seal intervals to prevent the infiltration of sealing material into the sand/gravel pack (**Figure-4, Figure-6A, Figure-6B**).

For nonvertical water wells and monitoring wells, this means that relatively long sections of the borehole, even if equipped with unperforated well casing, do not have to be sealed if they reside in the target aquifer or water bearing zone (**Figure-5**).

Cathodic protection wells. Annular space that is not opposite the conductive zone of a cathodic protection well must be sealed with approved sealing materials. Nonvertical sections of the borehole of cathodic protection wells, even if outside of the conductive zone, do not have to be sealed if they reside within a single aquifer or water bearing zone.

Geothermal heat exchange wells. GHEWs that are installed in a borehole must be sealed from ground surface to the total depth of the borehole. Nonvertical sections of the borehole of geothermal heat exchange wells do not have to be sealed if they reside within a single aquifer or water bearing zone.

6.4.2.2. Surface Seal

Water wells, monitoring wells, and cathodic protection wells. The surface seal interval is the uppermost 50 ft MD of the borehole. The top of the surface seal interval is at ground surface unless freezing conditions exist (see 6.2.2.2 Areas of Freezing) or if a vault is used, in which case it is at the bottom of vault. The surface seal may be between

the well and conductor casing or outside of the conductor casing (see Section 6.4.2.3 Conductor Casing Seal). The surface seal must be sand cement (Section 5.9.2.2 Sand Cement). (**Figure-7**)

Geothermal heat exchange wells. The surface seal interval is the uppermost 50 ft MD of the borehole. The top of the surface seal interval is at the header assembly. The surface seal may be between the well and conductor casing or outside of the conductor casing (see Section 6.4.2.3 Conductor Casing Seal). Approved materials for the surface seal do not differ from the formation seal (Section 6.3.2 Sealing Materials for GHEWs).

6.4.2.2.1. Shallow Groundwater

A variance to the 50 ft MD minimum surface seal length (Section 6.4.2.2 Surface Seal) may be requested in areas of shallow groundwater, where the target zone for production or monitoring necessitates a shorter seal. For a water well (except remediation extraction wells for regulatory purposes – see below), in no case shall an annular seal extend to a total depth less than 20 feet TVD.

For monitoring wells and remediation extraction wells, the surface seal may be reduced as needed. A monitoring well with a reduced surface seal length less than 20 ft TVD, must be constructed only in first encountered groundwater and not completely penetrate a confining layer that separates shallow groundwater from deeper water per Section 6.4.2.4.1 Sealing Requirements to Prevent Cross-Flow and Contamination Between Aquifers. Caution should be exercised when locating a well with a surface seal shorter than 50 feet TVD with respect to sources of pollution and flooding (Section 4.4 Well Location with Respect to Sources of Pollutants and Section 4.1 Flooding). Such precautions include horizontal separation distances greater than those in Table 4-1.

6.4.2.2.2. Areas of Freezing

The freezing depth, frost line, or frost depth is the depth of soil that is likely to experience freezing. In freezing areas, the top of a cementitious surface seal should be below the freezing depth. The freezing depth can be determined from local building codes. In no case shall the top of the surface seal be more than 4 feet below ground surface. In all cases, the annular space above the top of the seal should be either backfilled with a bentonite-based sealing materials or compacted soil.

6.4.2.3. Conductor Casing Seal

If permanent conductor casing is installed, it must be sealed against the borehole wall along its entire length with sand cement regardless of its length. Conductor casing seals that are less than 50 ft in length must be accompanied by a surface seal. A formation seal installed below the conductor casing must overlap at least 10 feet with the conductor casing seal (**Figure-7**).

Refer to Section 7.3 Temporary Conductor Casing for requirements for temporary conductor casing.

Gravel-to-the-Surface Wells

For gravel-to-the-surface wells, where the annular space between the conductor and well casings is filled with gravel pack, the conductor casing seal serves as both the surface and formation seals and must conform to the requirements of Sections 6.4.2.1 General Requirements, 6.4.2.2 Surface Seal, and 6.4.2.4 Formation Seals, and 6.4.2.4.1 Sealing Requirements to Prevent Cross-Flow and Contamination Between Aquifers (**Figure-7**). For gravel-to-the-surface wells, special provisions for surface construction features apply (Section 6.5.2 Base).

6.4.2.4. Formation Seals

All seals that are below the surface seal and/or the conductor casing seal are referred to as formation seals (**Figure-7**).

If a confining layer is identified adjacent to the target aquifer or the conductive zone, then the formation seal must extend at least 10 ft into the confining layer. If the confining layer is less than 10 feet thick, the seal must penetrate the entire confining layer (**Figure-9**). If conductive concrete is used as a formation seal, anodes that are embedded in the conductive concrete must not be located less than 10 feet from confining layers that separate aquifers or water bearing zones.

Water wells, monitoring wells, and cathodic protection wells. Formation seals may be constructed with any of the materials in Section 5.8 Approved Sealing Materials.

Geothermal heat exchange wells. Formation seals must be constructed in accordance with Section 6.3.2 Sealing Materials for GHEWs.

6.4.2.4.1. Sealing Requirements to Prevent Cross-Flow and Contamination Between Aquifers

If a well penetrates more than one aquifer or water-bearing zone, and one or more of the aquifers or water-bearing zones contains water that, if allowed to mix, will degrade the quality of water in the other aquifer(s) or water-bearing zone(s), the annular space opposite the aquifer(s) or water-bearing zone(s) producing such poor-quality water must be sealed. This requirement does not apply to nested monitoring well structures with isolated well screens and intervening seals.

Wells must not be screened or have perforated vent pipe above and below any confining layer that is either:

- 1) A known/named/mapped/interpreted confining layer, based on existing information, provided and/or approved by the LEA, or
- 2) More than 50 feet thick.
- 3) Separating confined and unconfined aquifers.

A confining layer meeting either 1, 2, or 3 above must be sealed in accordance with Section 6.4.2.4 Formation Seals.

Figure-10A, Figure-10B

6.4.3. Transition Interval and Transition Seals

A transition seal may be placed in the interval between the gravel pack (or the conductive zone in the case of cathodic protection wells) and the annular seal to prevent sealing material from infiltrating the gravel pack (or conductive backfill) or as a “foundation” to support the annular seal column above. All approved sealing material components and materials in Sections 5.8 Sealing Material Components and 5.9 Approved Sealing Materials, may be used in transition intervals. Cementitious transition seals should be allowed to set, and bentonitic transition seals should be allowed to hydrate, before the annular seal is placed. The top of the transition seal must be sounded to ensure that no bridging of the material over unfilled voids has occurred during placement.

The transition seal must not interfere with the annular seal. In cathodic protection wells, the length of the transition seal must not exceed 5 feet.

6.5. Surface Construction Features

6.5.1. Openings

Protection from Foreign Matter

All openings providing access into the well from the surface must be protected against entrance of surface water or foreign matter with watertight caps or plugs. This excludes access openings designed to permit the entrance and/or egress of air or gas (air or casing vents), which must be protected against the entrance of foreign material by installation of down-turned and screened “U” bends, protective well housing, or other effective means (**Figure- 11**).

All other openings (e.g., holes, crevices, cracks, etc.) must be sealed.

Monitoring and Sampling Access

Water wells must be equipped with infrastructure, such as a sounding port or an airline, to reliably determine groundwater levels in the well. Water wells must be equipped with infrastructure, such as a sample port, to reliably obtain groundwater samples prior to discharged groundwater entering a holding tank.

Sealing the Pump Head

Where the pump is installed directly over the casing, a watertight seal (e.g., gasket) must be placed between the pump head and the pump base (concrete slab), or a watertight seal must be placed between the pump base and the rim of the casing, or a

well cap must be installed to close the annular opening between the casing and the pump column pipe (**Figure-11**).

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 must be closed by a watertight seal or well cap.

A watertight seal must 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 (**Figure-11**).

Relative Elevation of Openings

Secondary Containment Areas

Openings that are located inside secondary containment areas associated with industrial facilities (e.g., near petroleum pipelines, tank farms, fueling terminals, water and wastewater treatment facilities) must be no less than 12 inches above the highest elevation of the secondary containment structure.

Spill Areas

Openings associated with wells that are constructed in industrial areas subject to potential spills (e.g., near petroleum pipelines, tank farms, fueling terminals, water and wastewater treatment facilities) must be no less than 12 inches above the calculated spill elevation.

Outside the 100-Year Flood Zone Outside 100-year flood zone (Section 4.1 Flooding), the top of the well casing and any openings into the top of the well must be no less than 12 inches above pre-existing grade or 12 inches above the vault floor if a vault is used. If the vault for a cathodic protection well cannot reasonably be located in an area that (1) is not subject to inundation by overland flow, shallow concentrated flow, or ponding of surface water runoff and (2) cannot be built up so that drainage moves away from the well and the base is not subject to local ponding (Section 4.2 Surface Drainage), then the vent pipe should be routed to terminate outside of the vault, no less than 12 inches above grade (**Figure-6A, Figure-6B**).

Inside the 100-Year Flood Zone

Inside 100-year flood zone (Section 4.1 Flooding), above-ground well components must be constructed to withstand flood-related loads, including the effects of buoyancy, hydrodynamic forces, and debris impact. There are two construction options:

Option A: The top of the well casing and any openings into the top of the well must be no less than 12 inches above the 100-year flood elevation. For FEMA 100-year flood zones without published base flood elevations, that information must be provided by the LEA.

Option B: The top of the well casing and any openings into the top of the well must be no less than 12 inches above grade. Openings designed to permit the entrance and/or egress of air or gas, must be constructed to prevent surface water from entering the well structure.

Public water supply wells must be protected against flooding in accordance with the California Waterworks Standards (California Code of Regulations, Title 22, Division 4, Chapter 16), which requires that "Each new air-release, air vacuum, or combination valve, and any such valve installed to replace an existing valve shall be: (a) Installed such that its vent opening is above grade, above the calculated 100-year flood water level, and, if recorded data are available, above the highest recorded water level;..." In addition, the California Waterworks Standards require that a public water supply well's wellhead terminates a minimum of 18 inches above the finished grade.

6.5.2. Base

A concrete base or pad must be constructed at ground surface around the top of the well casing and contact the annular seal, unless freezing conditions exist (see 6.2.2.2 Areas of Freezing) or the well terminates in a vault below ground surface (Section 6.5.3 Well Vaults).

The upper surface of the base must slope away from the well casing. The base must extend at least two feet laterally in all directions from the outside of the borehole wall. For example, for a 12-inch borehole, the pad must have a minimum diameter of 5 feet or, if rectangular, a minimum side length of 5 feet. (**Figure-12**)

The base must be a minimum of 4 inches thick. The base must extend a minimum of 2 inches below ground surface. The pump base must be designed and constructed to withstand the weight and forces associated with the pump equipment.

The base must 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 watertight and must not cause the failure of the annular seal or well casing.

Gravel-to-the-Surface Well

A gravel-to-the-surface well that is constructed with gravel pack extending to the ground surface within the annular space between the well and conductor casings (Section 6.4.2.3 Conductor Casing Seal), must not terminate in a vault and must not be completed with below-ground discharge (i.e., pitless adapter). These wells must have a watertight cover installed between the conductor casing and the inner casing, and the watertight cover must be encased with concrete and bonded to the base.

6.5.3. Well Vaults

Where conditions or situations require the use of a vault, it must be structurally sound, protected against the entrance of surface water or foreign matter, and must prevent surface water from pooling or ponding around the vault. The top of the vault (commonly referred to as utility box or pull box in the context of cathodic protection wells) must be set at, or above, grade.

The vault must be large enough to provide safe working space for the installation and must allow sufficient space for approved electrical splices. All local, State, and federal laws pertaining to excavation must be followed, including U.S. Department of Labor Occupational Safety & Health Administration (OSHA) Safety and Health Regulations for Construction — Excavations (Code of Federal Regulations 29 CFR 1926 Subpart P).

The vault must be set into or in contact with the surface seal as follows:

- The top of the surface seal (floor of vault) must be no more than 4 feet below ground surface.
- The surface seal must be allowed to settle and set for 24 hours prior to emplacement of the vault.
- The vault must then be placed into the surface seal material used to “top off” the annulus before it sets.

The space between the outer walls of the vault and the excavation into which it is placed must be filled with a cementitious sealing material to form a proper, structurally sound foundation for the vault, and to seal the space between the vault and excavation.

The concrete base must be a minimum of 4 inches thick, free of cracks or voids, and provide a structurally sound and watertight connection to the surface seal.

Venting of gases must be provided, as needed (e.g., not for wells designed to draw a vacuum, such as "double-cased" or "casing path" wells), either through the vault lid or through an auxiliary vent pipe. Openings of any conduits or vent pipes must conform to Section 6.5.1 Openings.

The lid must be able to be secured against unauthorized access and marked in accordance with Section 6.5.9 Markers.

The vault and its lid must be strong enough to support vehicular traffic if such traffic could occur and should have an appropriate load rating for the site conditions.

6.5.3.1. Inside the Vault

Openings, including the top of casing, must conform to Section 6.5.1 Openings.

Additional Input Needed from TAC on Drainage Requirements for Vaults. The following is based on the CGA Article 290, Below Grade Well Head Discharge:

A proper drain is installed at the base of the vault. Gravel, rock, or soil bottoms are unacceptable and should never be used. The drain size should be considered based on the size of the vault, capacity of the pump in the well, and the maximum volume of any water that could run off into the vault from the discharge. The minimum size of the drainpipe should be 2" I.D. The drainpipe should terminate at daylight and should be fitted with a protective screen. If it is not possible to exit at daylight, then in lieu of a drain a completely watertight seal may be provided. If neither of these options is available, then a vault should not be used.

6.5.4. Pitless Adapters

Where conditions or situations require the use of a pitless adaptor, surface construction may be either above or below grade. The pitless adapter or pitless unit and installation procedures in above and below ground surface installations must adequately prevent the entrance of surface water, dirt, animals, insects, or other foreign matter.

The pitless adaptor must be lead free and conform with National Sanitation Foundation (NSF) / American National Standards Institute (ANSI) NSF/ANSI 61/372 compliant and must be properly rated for all expected loads (e.g., weight of piping and equipment).

The top of the casing must be equipped with a watertight seal with removable access ports for monitoring and sampling in accordance with Section 6.3.1 Openings.

Access for venting of gases must be provided as needed (e.g., not for wells designed to draw a vacuum, such as "double-cased" or "casing path" wells). Openings of any conduits or vent pipes must conform to Section 6.3.1 Openings.

Where the well casing and annular seal do not extend above ground surface, a concrete base or pad must be constructed as a permanent location monument for the covered well. The base must be 3 feet in length on each side (or diameter) and 4 inches in thickness. The base must have a lift-out section, or equivalent, to allow access to the well. The lift-out must facilitate inspection and repair of the well. Section 6.3.8 Markers includes requirements for well markers.

A watertight seal must be provided where discharge piping exits from the wall of the casing. The seal must be capable of withstanding (with safety factor) maximum system pressure, including surge. If applicable, a watertight seal must also be provided in situations where electrical wiring exits the wall of the casing.

When installation causes the annular seal to be breached, new concrete must be poured around the pitless discharge.

6.5.5. Pump Blowoff

When there is a blowoff or drain line from the pump discharge, it must be located above any known flood levels in accordance with Section 6.5.1 Openings, and it must be protected against the possibility of backsiphonage or backpressure. The blowoff or drain

line must not be connected to any sewer or storm drain except when connected through an air gap.

6.5.6. Casing Air Vents

Casing air vents are required for all water wells, for wells designed to draw a vacuum, such as "double-cased" or "casing path" wells.

6.5.7. Back Flow Prevention

All pump discharge pipes not discharging or open to the atmosphere must be equipped with an automatic device to prevent backflow and/or back siphonage into a well.

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 must be equipped with a backflow prevention device(s).

Automatic water make-up systems for GHEW's that are connected to a water well or other water supply source, including domestic, municipal, or other drinking water systems, must be protected with a backflow prevention device that complies with the California Plumbing Code.

6.5.8. GHEW Pressure Relief Valve Installation

For GHEWs with automatic water make-up systems, a pressure relief valve must be installed directly downstream of the water make-up system to prevent system over-pressurization. The relief valve must be set so that the maximum system pressure will not be exceeded at any point in the system. All waste flow from the relief valve must be captured for proper disposal. See also Section 8.8 GHEW Pressure Relief Valve Maintenance.

6.5.9. Markers

All wells must be permanently marked with the DWR-issued State Well Number, Well Completion Report Number, Owner's Well Number, local well name, or other well identification that is included on the well's Well Completion Report to facilitate unambiguous identification and correlation between well structure and Well Completion Report in the field. This marking can be achieved with corrosion resistant steel placards that are fastened to non-removable parts of the wellhead including the casing, the concrete base, or vault. If the well terminates in a vault, such marking must be provided inside the vault. For cathodic protection wells, well identification information must also be contained in the rectifier box along with distance and direction to the cathodic protection well.

Monitoring wells must be clearly and permanently labeled "MONITORING WELL" or "MW."

Marking of Well Vaults

The outside of the vault lid of a monitoring well must be clearly and permanently labeled "MONITORING WELL" or "MW." The outside of the vault lid of a cathodic protection well must be clearly and permanently labeled "CATHODIC PROTECTION WELL", "CATHODIC PROTECTION", "ANODE" or "CP."

Marking of Paved-Over Cathodic Protection Wells

Marking must be directly above the borehole, flush with ground surface in brass monument.

6.5.9.1. Underground Markers for GHEW

Two types of underground markers must be used for detecting buried components of a GHEWs during future excavation activities:

1. Metal markers enable the location of a loop field by use of a metal detector before excavation begins.
2. Visual markers enable the visual detection of a loop field before buried loop field components are encountered during excavation.

All water-based GHEWs must have both types of underground markers. The two types may be combined, e.g. high-visibility polyethylene tape with integral metallic wire. Only high-visibility tape is required for refrigerant-based systems since copper tubing is detectable with a pipe-cable locator.

Metal in markers must be coated or otherwise encapsulated to be corrosion-resistant. Visual warning tape or tags, and related labeling, must be a highly visible color and must not degrade underground.

Underground markers must be installed at detectable depths in the following locations:

- For vertical and inclined systems, markers must be installed above all borehole openings and header assemblies.
- For HDD systems, high tensile-strength marking tape and wire must be pulled through the borehole along with the ground loop pipe. Markers must also be installed above all header assemblies.
- For excavated systems, markers must be laid along the perimeter of the loop field and within the loop field footprint at sufficient intervals to permit detection of loop field components.

Surface signage, and construction records that include location information such as GPS coordinates, may be used in addition to required underground markers to aid in the location of buried system components.

1.2. System Labels for GHEW

The following information must be prominently displayed using a permanent tag or label affixed at the same general location where a GHEW is flushed, purged, and filled:

- Type, concentration, and volume of heat exchange fluids and additives (i.e. water, freeze protection additives, corrosion inhibitors, refrigerant, and lubricating oil, where applicable)
- The following text: "Groundwater Heat Exchange System -- WARNING: Use only heat exchange fluids and additives identified on this label. All other fluids and additives, including ethylene glycol, are STRICTLY PROHIBITED."
- Name, contractor's license number, and telephone number of the installing contractor.

1.10. Protection from Accidental Damage

Areas of vehicular traffic, above-grade wells: Protective steel posts or equivalent measures of protection must be installed to protect the well structure, including cathodic protection well vent pipe, from vehicular impact. The posts or equivalent protective measures must be highly visible.

Non-vehicular traffic areas, above-ground features: The wellhead must be protected commensurate with the site-specific risk of accidental damage (e.g., from foot traffic, animals, landscaping equipment, etc.). For cathodic protection wells, if not protected by the rectifier or a dedicated mounting post or bollard, the surfacing vent pipe must be co-located with an existing rigid structure (e.g., power pole or electrical cabinet).

7. Construction

7.1. Underground Service Alert

To protect underground infrastructure and public safety, all drilling and excavation operations must be completed in accordance with the California One Call Law (California Government Code Sections 4216 through 4216.9), and in consideration of the most recent version of Common Ground Alliance's *Best Practices*. Per Government Code Section 4216 et. seq., the appropriate regional notification center (Underground Service Alert of Northern/Central California and Nevada, or Underground Service Alert of Southern California) must be contacted to locate and mark subsurface installations prior to any drilling or excavation work. Owners of subsurface installations that are not covered by the regional notification center, such as septic lines and sewer connections, must be contacted directly to locate and mark their subsurface facilities.

7.2. Casing Handling and Installation

Well casing must be assembled and installed with sufficient care to prevent damage to casing sections and joints. Casing and joints above intervals of perforations or screen must be watertight.

Whenever pipe installation or joining is interrupted, the pipe ends must be capped to prevent animals, water, dust, dirt, mud, and other foreign matter from entering the pipe.

Manufacturer's guidelines and industry best practices must be followed during the storage, transport, handling, and installation of casing and fittings to prevent damage. Pipe and fitting manufacturers can provide special handling procedures for cold weather conditions.

Excessive bending of pipe and fittings must be avoided. Bending must be within the limits specified by the manufacturer for the type, grade, wall thickness, and diameter of casing and fittings.

Metal Casing. Metal casing may be joined by welds, welded collars, threads, splines, or threaded couplings. Welding must 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. Metal casing must be equipped with a "drive shoe" at the lower end if it is driven into place.

Plastic Casing (Water Wells, Monitoring Wells, and Cathodic Protection Wells).

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 must meet specifications for the type of plastic casing used. Solvent cement must be applied in accordance with solvent and casing manufacturer instructions. Particular attention must 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 must be met:

- ASTM D2564, "Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings"
- ASTM D2855, "Standard Practice for Making Solvent-Cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings"

Plastic casing or screen must not be subjected to excessive stress during installation and must not be driven into place. Care must be taken to ensure that plastic casing and joints are not subjected to excessive heat from cementitious sealing material. A specifically designed adapter must be used to join plastic casing to metallic casing or screen.

7.3. Temporary Conductor Casing

Temporary conductor casing that is installed solely to aid in the drilling process without sufficient annular space and provisions, such as centralizers, to allow for the placement of a conductor casing seal according to these standards (Sections 6.4 Seals and 7.6 Placement of Sealing Material), must be removed as the surface seal is placed between the well casing and borehole wall. The sealing material must 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. If this temporary conductor casing is not removed during well installation, the well must be destroyed in its entirety in accordance with these standards.

7.4. Aquifer Isolation During Construction

If polluted soil or groundwater (Section 4 Site Planning) will be penetrated during drilling and drilling activities could mobilize those pollutants before sealing material can be installed, then precautions must be taken to seal off or isolate those polluted zones during drilling and well construction operations. Special precautions could include the use of conductor casing, borehole liners, maintaining drilling fluid in the borehole for positive pressure such that formation water cannot enter the borehole, and specialized drilling equipment.

7.5. Provisions for GHEWs

7.5.1. Drilling Restriction

Refrigerant-based systems must not be installed with HDD methods.

7.5.2. Casing Handling and Installation

7.5.2.1. Field Joining of Pipe and Fittings for GHEW

General Requirements

Field joining is permitted only for the header assembly. Any connections within a borehole must be joined inside in a controlled environment, such as a factory, workshop, or fabrication facility, according to pipe manufacturer's instructions.

Joining HDPE

HDPE connections must be heat fused according to pipe manufacturer's instructions and ASTM F2620, *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*.

Joining PEXa

Field joining of PEXa tubing can be accomplished using either of two acceptable methods:

- PEXa tubing may be fused in the field using only polymer electrofusion fittings installed in accordance with the manufacturer's published procedures.

- Cold-expansion fittings with metal compression sleeves may be used for direct buried PEXa connections when installed according to ASTM F2080, *Standard Specification for Cold-Expansion Fittings with Metal Compression-Sleeves for Cross-Linked Polyethylene (PEX) Pipe*, and the fitting manufacturer's published procedures. A manufacturer-approved corrosion covering must be used.

Joining Copper for Refrigerant-Based Systems

Copper joints must be brazed, butt-welded, or soldered using a lead-free solder, following applicable requirements of ASME B31.5, *Code for Pressure Piping, Refrigeration Piping and Heat Transfer Components*, and ASTM Standard B828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings*.

7.5.2.2. Placement Into Boreholes

- Field joining is not permitted for connections within a borehole. Any connections within a borehole must be joined inside in a controlled environment, such as a factory, workshop, or fabrication facility, according to pipe manufacturer's instructions. Field joining is permitted only for the header assembly (Section 7.5.2.1 Field Joining of Pipes and Fittings for GHEW).
- Only potable water, air, or an approved heat exchange fluid in accordance with Section 5.9.4 GHEW Heat Exchange Fluids may be placed inside the ground loop during its installation.
- The ground loop must not be forced past any obstructions within the borehole, since this could damage the loop material and compromise its integrity. If an unremovable obstruction is encountered in a vertical or inclined borehole that prevents the installation of the loop to the desired depth, provisions must be made for either sealing the borehole beyond the obstruction before installing the ground loop, or destroying the entire borehole through full-length sealing in accordance with Section 9 Destruction.
- External weights may be attached to the ground loop in a manner that does not damage the pipe or fittings to facilitate insertion of pipe and fittings to the desired depth. Weights must be made of nontoxic, nonleaching materials.
- Loop pipe ends must remain capped and protected until ready to be connected.
- The placement of polyethylene pipes and fittings using HDD must follow best practices outlined in industry standards, such as the PPI TR-46: *Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of High Density Polyethylene Pipe*, the HDD Consortium's *Horizontal Directional Drilling Good*

Practices Guidelines (Bennett and Ariaratnam 2008), and the *PPI Handbook of Polyethylene Pipe*.

- PEXa manufacturers should be consulted concerning installation of PEXa pipes using HDD.

Request for TAC Input: Can we replace the above recommendation associated with the use of PEXa pipes in conjunction with HDD with something more useful? Is PEXa compatible with HDD under all circumstances, or is it not?

7.5.2.3. Placement into Excavations

Pipe placed in excavations must be laid and bedded in accordance with pipe manufacturer's specifications for bedding and embedment material, including the maximum allowable particle size, vertical thickness, and degree of compaction. Sharp objects, such as loose rocks, large dirt clods, and debris must be removed from the excavation when placing bedding or embedment material. Bedding and embedment material must not contain organic matter, debris, or other unsuitable materials.

For water-based systems, the installation of polyethylene pipes must conform to the requirements of ASTM F1668, *Standard Guide for Construction Procedures for Buried Plastic Pipe*.

7.5.3. Pressure Testing Ground Loops

WARNING: Pipe or fitting failure during a pressure test can be sudden and explosive, especially if compressed gas (e.g., air) is used. Death, serious injury, and property damage can result. A pressure test must not be conducted on any section with damage (e.g., scratches, cracks, or gouges) outside of the manufacturer's specified tolerances. Test pressures must not exceed the test pressure rating of the lowest rated pipe component, including fittings.

7.5.3.1. Pre-Installation Pressure Test

An initial pressure test of individual ground loops must be conducted prior to their installation to verify that loop pipes and U-bends have no leaks. The pressure test must be performed according to the manufacturer's specifications, taking all necessary safety precautions to protect life and property.

If leaks are detected in a ground loop prior to insertion into the borehole, the loop cannot be used and must be replaced.

7.5.3.2. Post-Installation Pressure Test

7.5.3.2.1. Water-Based Systems

Following completion of all field joining and before connecting to the mechanical equipment, a pressure test of the loop field must be conducted with potable water in accordance with ASTM F2164, *Standard Practice for Field Leak Testing of Polyethylene*

(PE) *Pressure Piping Systems Using Hydrostatic Pressure*. As described in ASTM F2164, the loop field may be partially backfilled prior to testing, leaving joints and fittings exposed to facilitate inspection for joint leakage. Pressure testing under freezing conditions may require special considerations.

Any leaks discovered during the pressure test must be repaired and the loop field must be retested. If leaks cannot be corrected, faulty components must be isolated and destroyed in accordance with Section 9 Destruction.

Upon conclusion of the pressure test, the GHEW loop field should be maintained under pressure until it is connected to the building heat exchange system.

7.5.3.2.2. Refrigerant-Based Systems

Following connection to the header assembly/manifold, refrigerant-based system loop fields must undergo pressure and leak testing in accordance with requirements of ASME B31.5 Section 538, *Testing*.

Any leaks discovered during system evacuation or testing must be repaired and the system must be retested. If leaks cannot be corrected, faulty system components must be isolated and destroyed in accordance with Section 9 Destruction. Any test fluid removed from the system must be handled and disposed of in accordance with all applicable federal, State, and local regulations.

7.6. Placement of Sealing Material

This section addresses placement of annular sealing material during construction and placement of sealing material to destroy a well in accordance with Section 9 Destruction.

7.6.1. Heat of Hydration

Heat of hydration developed by cementitious sealing materials must be accounted for and necessary precautions must be taken to prevent casing damage or collapse during the placement of sealing material.

7.6.2. Considerations for HDD Boreholes

Grouting during pullback of ground loop pipe is generally not recommended because of the risk of the sealing material hydrating or setting before pullback is complete. The following U.S. Army Corps of Engineers (USACE) procedure for grouting HDD systems should be observed, where possible (Latorre et al. 2002):

In this procedure, grouting tubes [or “slicklines”] would be inserted as far as possible into the borehole after the pipe is pulled back. [In general, grouting tubes can be inserted up to approximately 150 feet, according to the HDD Consortium (Bennett and Ariaratnam 2008).] The grout mixture would be pumped into the annulus through these tubes until grout returned to the surface at the entry or exit of the pipeline. Grouting pressures must be carefully controlled to minimize risks of hydrofracture.

7.6.3. Obstructions

All drill cuttings and other obstructions to sealing must be removed prior to placement of sealing material.

7.6.4. Timing

Sealing must be placed as soon as practical following casing installation (during construction), or casing removed (during destruction).

The annular space must not be left unsealed longer than 24 hours following the installation of the casing, without approval of the LEA.

Any open boreholes must be covered (Section 7.11 Temporary Cover) until the casing can be installed and sealed, to protect against pollution of groundwater through the open borehole and to prevent a safety hazard to humans and animals.

7.6.5. Method of Placement

General Requirements

Sealing material must be placed in one continuous operation from the bottom of the interval to be sealed, to the top of the interval. If interruptions occur during sealing operations that necessitate multiple lifts, settled materials (e.g, from drilling fluid, or caving of the borehole) must be removed from the annular space before the next lift is placed (e.g., by circulating, jetting, or other means).

All sealing materials, whether slurry or non-slurry, must be placed by methods that prevent freefall (see "Freefall Exception" below), bridging over unfilled voids, dilution of the sealing material, or separation of sand or aggregate from the sealing material. Such methods include the use of a tremie pipe or hollow stem auger. The inner diameter of the tremie or auger stem must be adequate to allow the placement of the material.

During seal placement, the top of the sealing material should be measured regularly in the borehole with a weighted tape, or "tagged." Note that this is not feasible during pressure grouting.

Placement by Tremie or Auger Stems

When placing slurry materials, the discharge end of the tremie or auger stems must be kept submerged in the freshly deposited slurry as the material is being placed and as the tremie pipe or auger stems are withdrawn.

Non-slurry materials must only be placed in vertical boreholes and nonvertical boreholes that are greater than 45 degrees from horizontal.

When placing non-slurry materials (i.e., bentonite granules, chips, or pellets), the discharge end of the tremie or auger stems must be kept no more than one tremie pipe

or auger pipe length above the freshly deposited material. When placing non-slurry materials in a wet hole, it must be circulated with fluid through the tremie.

Chips must be screened prior to placement to reduce likelihood of bridging of the material leaving unfilled voids below. Placement and hydration of chips and pellets must be conducted in accordance with manufacturer's instructions.

Freefall Exception

Freefall placement of sealing materials without use of a tremie or auger stems is not permitted, except in vertical boreholes and nonvertical boreholes that are greater than or equal to 45 degrees to horizontal, where the interval to be sealed is dry and no deeper than 30 feet TVD.

Freefall placement of sealing materials without use of a tremie or auger is not permitted in boreholes less than 45 degrees from horizontal.

Recommendation for Non-Slurry, Non-Sealing Material

It is recommended that non-slurry, non-sealing material (e.g., gravel pack or coke breeze) be placed with the same methods as sealing materials to provide a stable foundation for annular seals. During placement, the top of the material should be measured regularly in the borehole with a weighted tape, or "tagged." The volume material placed must be compared to the calculated volume to be filled.

7.6.6. Minimum Set Times

Cementitious seals must be allowed to set, and bentonitic seals allowed to fully hydrate, before construction or development operations resume to prevent compromising the seal's integrity. During setting or hydration, the casing and borehole must be left undisturbed.

Minimum setting times required for sealing materials containing portland cement are:

Types I and II cement – 24 hours

Type III cement – 12 hours

Type V cement – 6 hours

More time may be required depending on site conditions.

Hydration times for bentonitic sealing materials should be provided by the manufacturer. Bentonite preparations normally require ½ to 1 hour to adequately hydrate. Actual hydration time is a function of site conditions and the form of bentonite used.

7.6.7. Flowing Conditions

“Flowing conditions,” in which subsurface pressure causes flow of groundwater out of the borehole onto the ground surface, must be controlled before proceeding with construction or destruction activities. Uncontrolled flow of groundwater at the surface from a borehole or well is prohibited by California Water Code sections 300 – 311, which requires that any artesian well with flowing conditions be plugged, capped, or equipped to prevent the uncontrolled flow of water from the well.

7.6.8. Verification of Seal Placement

Prior to seal placement, the bottom of the to-be-sealed interval must be measured with a weighted tape, or “tagged”. The top of the sealed interval must be tagged after seal placement.

The specific gravity of each fully mixed batch of sealing material must be measured with a mud balance prior to placement, and as sealing material returns from the borehole to ensure the sealing material is undiluted in the borehole.

Sealing material placed to the ground surface must be allowed to settle. Settled sealing material that leaves void space in the annular space or borehole (in the case of a destruction) must be topped off and allowed to set before surface construction activities begin. For GHEWs, if subsidence is not greater than the excavation depth for headers, there is no need to top off.

7.6.9. Volumetric Check

The volume of sealing material placed must be compared to the calculated volume to be sealed.

7.6.10. Witnessing the Seal Placement

The entire sealing process must be witnessed by either the LEA or a California licensed Professional Geologist or Professional Engineer designated by the LEA.

7.6.11. Pressure

Pressure required for placement of cementitious sealing materials must be maintained until sealing materials set.

7.7. Backfilling Excavations for GHEW

All excavations must be completely and properly backfilled as soon as possible after loop field pressure testing is completed. Backfill material must be clean soil conforming to the pipe and fitting manufacturer’s specifications. Backfill material must be free from clods, stones, boulders, debris, or other material that could damage pipe or fittings, or could create voids. Backfill should be mounded at the ground surface in case settling occurs.

At a minimum, excavations must be fully backfilled in lifts and compacted to:

- Provide at least three (3) feet of backfill above all buried components of a GHEW loop field, including ground loops, headers, loop connectors, and building supply and return lines.
- Achieve a hydraulic conductivity approximately equal to, or less than, that which existed prior to the excavation.
- Minimize settling.

7.8. Installation of Heat Exchange Fluid and Additives

The GHEW loop field may need to be purged of the test fluid before it is charged with an approved heat exchange fluid and additives (Section 5.9.4 GHEW Heat Exchange Fluids). The loop field must be monitored for leaks during and after the installation of the heat exchange fluid and additives in case there are previously undetected leaks, or if any new leaks were created by backfilling and compaction operations. If leaks are detected, they must be repaired and the loop field retested consistent with the requirements of Section 7.5.3 Pressure Testing Ground Loops. If leaks cannot be corrected, faulty components must be isolated and destroyed in accordance with Section 9 Destruction.

7.9. Well Development and Rehabilitation

Development, redevelopment, or reconditioning of a well must 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.

The following methods used for the development and rehabilitation of a well, when done with care, are acceptable:

- Pumping
- Introduction of chemicals designed for this purpose
- Brushing
- Surging and swabbing by use of plungers and surge blocks
- Surging by use of compressed air (i.e., "airlifting")
- Backwashing or surging by alternately starting or stopping the pump
- Jetting with water
- Sonic cleaning
- Vibratory explosives
- 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.

Rehabilitation methods which use explosives are acceptable provided they are in accordance with Section 9.2.3 Explosive Casing Perforation and Destruction, and are carried out according to the plan that was approved by the LEA.

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

Chemicals, water, and other wastes removed from the well must be disposed of in accordance with applicable local, State, and federal requirements.

7.10. Well Repair and Well Modification

Well repair or modifications, such as the deepening of a well, the installation of liners or patches, or the perforation of previously blank casing must meet the requirements of these standards. Only wells meeting the surface seal requirements of this standard are eligible for deepening.

7.10.1. GHEW Leak Prevention and Detection

A system pressure test must be performed after system repairs or modifications. Any leaks discovered during pressure testing must be repaired before the system is returned to service. The system must then be retested after repair operations to ensure that no leaks remain. If leaks cannot be corrected, faulty system components must be isolated and destroyed in accordance with Section 9 Destruction.

7.11. Temporary Cover

Whenever there is an interruption in work on the well of several hours or more (e.g., due to overnight shutdown, inclement weather, or waiting periods required for the setting up of sealing materials, or tests), the well opening must be closed with a cover to prevent the introduction of undesirable material into the well and to ensure the public safety. The cover must be held in place or "weighted-down" in such a manner that it cannot be removed except with the aid of equipment or tools.

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

8. Maintenance

8.1. Wellhead Control Zone

Water wells, monitoring wells, and cathodic protection wells. The area extending laterally 10 feet in all directions from the borehole wall must be in control of the well

owner. This is the wellhead control zone. The wellhead control zone must be kept clear of brush, debris, hazardous materials, and waste. The wellhead control zone must be kept free of cavities (e.g., holes caused by burrowing animals or erosion). The wellhead control zone must not be irrigated.

For public supply wells, the area extending laterally 50 feet in all directions from the borehole wall must be in control of the well owner consistent with CCR, Title 22, Division 4, Chapter 16, Section 64560.

8.2. Well Access

The wellhead or GHEW header assembly must be freely accessible for service and well destruction, through maintaining lateral and vertical clearance to accommodate all necessary truck-mounted equipment, until the well has been destroyed in accordance with these Standards. Access must be provided via the property itself or via easements or other proper accessibility agreements.

8.3. Upkeep (Water Wells, Monitoring Wells, and Cathodic Protection Wells)

Surface construction features (Section 6.5 Surface Construction Features) must be kept in working order. Compromised, damaged, or missing materials and apparatus such as caps, plugs, O-rings, gaskets, screens, backflow prevention devices, access pipes, blow-off valves, air vents, threads, bolts, and other fasteners, etc. must be repaired or replaced. Cracks in the surface pad, well base, or vault structure must be resealed. Vaults, pump houses, or well enclosures must be kept clean and dry and must not be used for any type of storage, except for instrumentation used in the collection of data associated with the well. Lids and covers, including those of any type of vault, must be kept fully functional. The structural and watertight integrity of exposed sections of well casing and discharge line must be maintained. Holes or other damage to exposed casing or discharge line, must be repaired

Markers must be maintained and if damaged or lost, must be replaced.

Regular water quality monitoring is recommended.

Records of all well repairs and modifications must be properly maintained.

It is recommended that steel well casing be inspected via downhole video log periodically and when the pump has been removed for other reasons, such as for repairs, maintenance, or modification.

Permanently Inactive Wells. “Permanently inactive wells” that have not been used for one year, are considered abandoned and must be destroyed immediately in accordance with these standards (Section 9 Destruction) unless the owner demonstrates “intent for future use” to the LEA and maintains the well in accordance with Health & Safety Code

Section 115700. Any permanently inactive well maintained in this manner must be inspected via downhole video log every 5 years.

A cathodic protection well is considered "abandoned" or permanently inactive under any of the following conditions:

- when its anodes are exhausted and cannot, or will not, be replaced;
- when the well has been replaced; when the well is no longer physically connected to a direct current source (such as a rectifier);
- when a well has not been energized for the past year;
- when current output requires a new well and the influence of the existing will not effectively contribute additional current to the structure.

8.4. Wetting of the Conductive Zone of Cathodic Protection Wells

The practice of introducing water or any other fluid into a cathodic protection well to improve functionality of the cathodic protection system, or for any other reason, must be preapproved and permitted by the Water Boards.

8.5. GHEW Leak Prevention, Detection, and Repair

Every practical leak prevention and detection measure must be taken to reduce the possibility of a heat exchange fluid leak and its potential impacts. Examples of leak prevention and detection measures include, but are not limited to, pressure testing and the use of pressure sensors, water meters, and automatic system shutdown devices. Heat exchange fluid quality monitoring should be performed periodically because changes in the color or chemistry of the heat exchange fluid may indicate leaks, corrosion, or other potential problems.

8.6. GHEW Cathodic Protection and System Inspection

Cathodic protection systems used with refrigerant-based systems should be inspected annually, or at an interval appropriate for the specific system, in accordance with industry standards, such as NACE International SP0169-2013, Standard Practice: Control of External Corrosion on Underground or Submerged Metallic Piping Systems, and manufacturer guidelines.

8.7. GHEW Make-up Fluids and Additives

Make-up heat exchange fluids and additives must be the same as those identified on the system label, as described in Section 6.5.9.2 System Label.

All heat exchange fluids and additives other than potable water must be added manually.

8.8. GHEW Pressure Relief Valve Maintenance

For GHEWs with automatic water make-up systems the pressure relief valve must be maintained so that the maximum system design pressure will not be exceeded at any

point in the system. All waste flow from the relief valve must be captured for proper disposal.

9. Destruction

Any well that is no longer used for its intended purpose, or that meets the definition of “abandoned,” must be destroyed according to these standards.

Proper destruction of a well consists of the complete sealing of the well structure using approved methods described in Section 9.2 Approved Methods of Destruction. Complete sealing of the well structure includes the inside of all casings, and the annular space that has not been previously filled with cementitious sealing materials. In intervals where the annular space is not sealed with cementitious sealing materials, blank casing must be perforated or removed.

Destruction of uncased boreholes is addressed in Section 9.1 Preparatory Work and Sections 9.2.1.1 Approved Sealing Materials and 9.2.1.2 Placement of Sealing Materials.

9.1. Preparatory Work

Prior to destruction, the well must be investigated to determine its details of construction, its condition, and whether there are obstructions that will interfere with the process of sealing.

At a minimum, details of construction to be determined are as follows:

1. Surface construction features
2. Total well depth
3. Casing material(s), their diameter(s) and wall thickness(es)
4. Intervals of blank casing and perforated casing
5. Intervals of seals and type(s) of sealing materials.

Except for GHEWs, the total depth of a well to be destroyed must be determined via direct measurement.

If the WCR is not available or provides insufficient well construction information, and there are no other reliable documents available with the well’s construction information, such information must be sought via field investigation.

The casing’s condition must be assessed prior to destruction. Casing assessment may require field investigation using techniques to visually inspect the well casing.

Identification of seal intervals may require the use of geophysical methods. Appendix D lists geophysical methods and tools that can be used to detect seals behind the well casing. **Request for TAC input:** The table at the end of Appendix D lists geophysical

methods supporting both Appendix A and D. We are seeking the TAC's help with completing, correcting, and expanding this table.

If cementitious seal intervals remain undetermined after desktop and field investigations, well destruction proceeds as if they did not exist.

1.1. Cleaning of the Well Structure

After removing all equipment, the well must be cleaned of all obstructions and undesirable materials that could interfere with sealing including debris, drill cuttings and any other materials settled at the bottom of the well, oil from oil-lubricated pumps, or other pollutants.

Equipment, oil, debris, pollutants, or soils containing, or suspected of containing contaminants removed from a well must be properly handled, contained, transported, and disposed of according to all federal, state, and local laws.

1.2. Removal of Heat Exchange Fluids from Loop Field

- A. Water-based systems – All heat exchange fluid must be displaced by flushing with potable water. Heat exchange fluids must be captured and disposed of in accordance with all applicable local, State, and federal requirements.
- B. Refrigerant-based systems – All heat exchange fluid (refrigerant) must be evacuated, captured, and disposed of in accordance with applicable local, State, and federal requirements.

5.2. Approved Methods of Destruction

Sections 9.2.1 Casing Removal and Sealing, 9.2.2 Mechanical Perforation and Sealing, and 9.2.3 Explosive Casing Perforation and Destruction are approved for the destruction of water wells, monitoring wells, and cathodic protection wells. GHEWs must be destroyed according to Sections 9.2.5 Destruction of Drilled GHEW Ground Loops and 9.5.6 Destruction of Excavated GHEW Ground Loops.

5.2.1. Casing Removal and Sealing

Overdrilling and pulling of the casing must not be used to destroy nonvertical wells less than 45 degrees to horizontal. In addition, overdrilling must only be used to destroy straight boreholes (i.e., not directionally drilled holes).

After casing is removed via overdrilling, pulling, or excavation, all undesirable materials must be removed from the borehole in accordance with Section 9.1.1 Cleaning of the Well Structure. In addition, all seal material, and gravel pack material must be removed. The borehole

must be cleaned to the total depth and diameter equal to or larger than the diameter of the original borehole.

5.2.1.1. Approved Sealing Materials

Section 5.9 Approved Sealing Materials may be used in the destruction of uncased boreholes as follows. Neat cement, sand cement, and bentonitic sealing material can be used below 50 feet MD. Bentonitic sealing materials must not be used in fractured rock. Sand cement must be used from the ground surface to 50 feet MD. Concrete may be used to destroy the entirety of an uncased borehole with a diameter of three feet or more (See Section 5.9.2.4 Concrete).

5.2.1.2. Placement of Sealing Materials

Section 7.6 Placement of Sealing Materials applies to the placement of sealing materials in uncased boreholes. Note that concrete with an aggregate size that is too large to be placed via tremie pipe may only be placed above 30 ft TVD per Section 7.6.5 Method of Placement "Freefall Exception."

5.2.2. Mechanical Perforation and Sealing

Blank well casing intervals, except those that are opposite of existing cementitious annular seals, must be perforated, punctured, or otherwise opened to allow sealing material to intrude into and fill the annulus between the well casing and the borehole wall and any other void spaces (**Figure-13**).

Each linear foot of blank casing that is mechanically perforated must have:

- A minimum of 3 square inches of open area.
- A minimum of 4 perforations located equally around the casing.

5.2.2.1. Approved Sealing Materials

Section 5.9 Approved Sealing Materials may be used in the destruction of mechanically perforated wells as follows. Neat cement must be used as the sealing material in all perforated sections of the well structure, including existing casing openings (e.g., screens, louvers, vent pipe openings, and any other openings). Sand cement may be used opposite intervals of existing cementitious annular seals and must be used from ground surface to 50 feet MD. Bentonite should not be added to the cement mix as the resulting increase in viscosity will impede the complete saturation of gravel pack with sealing material.

5.2.2.2. Placement of Sealing Materials

Additional Input Needed from TAC: In Phase 1 Focus Groups, DWR was asked to provide the following details for pressure grouting through mechanical perforations: size and number of perforations (see section 9.3.2), amount of pressure needed to force sealing material into the annular space, how long should the pressure be maintained, and length of lifts. The project team was not able to find a minimum standard for this

practice due to variable conditions. The team considered requiring staged pressure grouting, with each layer (aquifer or confining layer) grouted in one lift.

Following is the Pressure Grouting Method suggested by CCDEH and CGA (Recommended edits to California Well Standards Bulletins, January 3, 2019), but note that this method doesn't address staged pressure grouting with the use of packers:

B. Approved Pressure Grouting Method

The following method must be used for pressure grouting:

1. Before pressurizing, the entire casing must be completely filled with sealing material.
2. The sealing material must be pressurized to a minimum of 25 PSI (pounds per square inch).
3. 25 PSI of pressure must be maintained for at least 5 minutes or until at least an additional 1/3 of the volume of the casing of sealing material (in addition to the material pumped prior to pressurizing) is pumped into the well.

5.2.3. Explosive Casing Perforation and Destruction

Standards for well destruction using explosives that follow are adapted from the California Groundwater Association Standard Practice Article 800, Explosive Destruction Standard (McMillan, n.d.).

Note to TAC: The following sections on destruction with explosives likely include more detail than is needed in the California Well Standards. We've included it all to receive input on what pieces are important to include in the update.

5.2.3.1. Required Licensing for Purchase, Possession, Storage and Use of Explosive Materials in California

6. A current and in good standing Federal Explosives License (FEL) issued and regulated by the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF).
7. A current and in good standing California Blaster's License with Water Well Services Endorsement (Class F. Limited) issued by California Division of Occupational Safety and Health Administration (Cal-OSHA).
8. A current and in good standing Certificate of Eligibility issued and regulated by California Department of Justice (DOJ).
9. Locally Required Permits
- 10.

10.1.1.2. Required Licensing for Transportation of Explosive Materials

1. A current and in good standing Motor Carrier Permit issued and regulated by the Department of Transportation (DOT).
2. A current and in good standing Hazmat Transportation License issued and regulated by the California Highway Patrol (CHP).

1.3. The Blasting Plan Author

The Blasting Plan must be authored by a licensed blasting contractor who:

- Is in good standing with all appropriate Federal, State, and local agencies and departments charged with overseeing the procurement, transportation, storage, and use of explosives
- Has all necessary and current permits and licenses from all appropriate Federal, State, and local agencies and departments charged with overseeing the procurement, transportation, storage, and use of explosive
- Is knowledgeable and experienced with the use of explosives for well destruction; and
- Has knowledge regarding water well design and well construction techniques.

Note: Legal review regarding definition and qualifications of “responsible person(s)” will be conducted during next revision of update.

1.4. Documentation Provided by Blasting Company

The following documentation must be provided for each blasting operation.

1. Blasting company contact information
2. Blaster name
3. Well name or defining number
4. Well location
5. Well construction details when available
6. Blasting design showing intended perforation intervals
7. Total quantity of explosive materials to be used
8. Placement of explosive materials in well
9. Operating procedure
10. Estimated burst pressure at water well casing
11. Author of blast plan
12. Blasting company name

1.5. Seismographic Monitoring

Seismograph services must be offered for any blasting operation. Seismograph services can be provided by the blasting company or by a third party. Seismographs must:

1. Be specifically designed for blasting operations (Instantel Blastmate series of seismographs or equivalent)
2. Be able to output seismographic data immediately after detonation via onsite printout from the seismograph or onsite processing through computer software.

Peak Particle Velocity of detonation must never exceed 2 inches per second.

2.6. Material Safety Data Sheet

Material Safety Data Sheets (MSDS) for each explosive product used must be available on request.

2.7. Blast Design

General Requirements

- Blasting designs are to be written by a competent licensed blaster with experience in field applications of explosives
- Permits and requirements of all federal, state, and local authorities shall be implemented in blast design
- Blasting designs are to provide sufficient blast pressures to exceed burst ratings of the type of casing that is to be perforated
- Current casing condition at the time of destruction must be considered.

2.8. Recommended Minimum Charge Weights

The following are recommended minimum explosives charge weights for PVC and steel casing destruction.

PVC Casing

1. Schedule 40 to 120, measuring ¼ inch to 6 inches in diameter, a minimum of 25 grain per foot detonation cord.
2. Schedule 40 to 120, measuring 6 to 12 inches in diameter, a minimum of 50 grain per foot detonation cord.
3. Any Schedule, measuring greater than 12 inches in diameter, a minimum of 100 grain per foot detonation cord.

Steel Casing

1. Wall thickness greater than .25 inches and measuring 2 to 6 inches in diameter, a minimum of 100 grain per foot detonation cord.
2. Wall thickness of 0.188 inches and measuring 6 to 12 inches in diameter, a minimum of 100 grain per foot detonation cord.
3. Wall thickness of .25 inch or greater and measuring 6 to 10 inches in diameter, a minimum of 200 grain per foot detonation cord.
4. Any wall thickness and measuring 10 to 18 inches in diameter, a minimum of 50 grain per foot detonation cord in conjunction with 150-gram Cast Boosters.
 - Cast Boosters shall be evenly spaced along the detonation cord line.
5. Any wall thickness and measuring larger than 18 inches in diameter, a minimum of 50 grain per foot detonation cord in conjunction with 450-gram Cast Boosters.
 - Cast Boosters shall be evenly spaced along the detonation cord line.

Note: The blasting professional in charge shall always reserve the authority to change blast designs based on Safety Factors or Undisclosed information about the well design.

5.9. Annular Seal Perforation

Casing intervals with cementitious annular seals identified as part of Section 9.1 Preparatory Work must not be perforated unless there is evidence or suspicion of seal failure.

If perforating casing intervals with cementitious seals, extra safety measures shall be implemented to reduce the potential of fly material during explosive seal perforating operations.

5.10. Evaluation of Structures and Utilities

The area surrounding the blast zone must be surveyed for surface and underground structures and utilities. Surface and subsurface structures and utilities in the blast zone must be accounted for in the blast design.

5.11. Redundant Firing Systems

Redundant firing systems must be used to ensure proper detonation of the entire charge during deep set operations.

5.12. Use of Retarders in Seal Material

Cement set time retardant is recommended for wells deeper than 400 feet and required for wells deeper than 1000 feet. Without a set time retardant such as Delvo, cement will harden before the well can be filled and charges detonated. The result of this is

inadequate flow of cement into native formation after detonation. Deep wells should be completed in one continuous pour.

5.13. Multiple Detonations

Multiple detonations can result in sections of the well casing not being perforated and could allow mixing of native and seal materials and therefore should be avoided.

5.14. Down Hole Charge Control and Placement Methods

Two methods of charge placement are acceptable:

1. Weighted Charge Line - Using a weight at the bottom of the charge line to anchor the charge in the bottom of the well. Tremie pipe should be left 5 to 10 feet off the bottom of the well prior to sealing material placement to anchor the weight
2. PVC Control Pipe - This method requires PVC pipe, usually 1 inch in diameter, to be glued or threaded together and set in the well to total depth. The charge is attached to this line as it is being lowered into the well. This method gives positive control of the charge line as sealing material is being pumped to the surface.

A charge line should never be attached to the same pipe used to convey sealing material into the well. If the tremie pipe becomes compromised, the charge line will also become compromised. Example: Tremie pipe becomes plugged and must be extracted, the charge will also be extracted.

Tremie pipe used to place sealing material should be placed prior to installation of charge line. After seal placement has begun and charges are anchored, the tremie pipe can be removed as necessary until sealing material has reached the surface.

5.15. Surface Containment

The Blaster in Charge must determine to contain potential surface splash or to distance personnel and equipment from the splash. If surface containment of potential sealing material splash is required, options to prevent splash include use of front loader buckets, backhoe buckets, plywood tents, tarps, plastic sheeting.

Metal objects such as well caps and discharge manifolds should never be used as containment devices. In the event of seal material evacuation, these may become dangerous projectiles.

5.16. Storage and Handling of Explosive Materials Onsite

1. All explosive materials to be used on the day of operations must be stored and transported in a Type 3 Day Box that meets ATF requirements at minimum:

- i. Construction: No less than 12-gauge steel, lined with either at least ½" plywood or ½" Masonite-type hardboard.
 - ii. Doors: Must overlap sides by at least 1"
 - iii. Locks (Hood not required): One steel padlock with at least 5 tumblers and casehardened shackle of at least 3/8" diameter.
 - iv. Unattended storage: Explosives must be removed to an appropriate magazine for unattended storage
2. Detonators must be stored separately from explosives. Minimum separation between explosives and detonators must be at least 18 inches.
 3. All explosive materials are to be handled by the Blaster in Charge or his or her authorized apprentice(s) only.
 4. All unauthorized personnel are to be relocated to a safe distance designated by the Blaster in Charge during loading procedures.
 5. All personnel are to be relocated to a safe distance designated by the Blaster in Charge during firing procedures.
 6. Detonators may not be attached to blasting machines or triggers under any circumstance until the blast zone has been cleared and the Blaster in Charge is ready to fire.

5.17. Blasting Safety Plan

A Blasting Safety Plan will be prepared for each well. The Blasting Safety Plan must include the following:

1. Hazard and risk assessment
2. Storage Plan
3. Transportation Plan
4. Blast design
5. Loading procedure
6. Misfire, hang fire, partial fire procedure
7. Surrounding area notification plan
8. Local authority communication plan
9. Material Safety Data Sheets
10. Emergency plan
11. Initiation or firing plan

11.18. Explosive Materials

1. Explosives used for water well procedures must only be consisted of molecular type explosives.

2. Explosives used must not leave behind any traces of contaminants.

Note: Element information is found on the MSDS for each product.

3. Only NONEL or Non-Electric initiation must be used in congested areas.

Note: NONEL or Non-Electric systems cannot be accidentally detonated by radio waves, cellular waves, static electricity, or errant stray current.

4. Explosives used must be waterproof or water resistant for a minimum of 24 hours without losing potency or sensitivity.
5. Blasting Caps must be of the instant time delay type or very near.

11.19. Approved Sealing Material

Sand cement may be used as a sealing material for the entire well structure.

Neat cement may be used as a sealing material up to a TVD of 50 feet.

Sand cement must be used from a TVD of 50 to ground surface.

5.4. Cement-Sealed Wells

"Cement-sealed wells" with an intact cementitious annular seal and no sections of blank casing that require perforation (i.e., without cementitious sealing materials behind them) can be destroyed without casing removal or perforation.

5.4.1. Approved Sealing Materials

Section 5.9 Approved Sealing Materials may be used in the destruction of cement-sealed wells as follows. Neat cement must be used as the sealing material in all sections of the well structure with existing perforations (e.g., screens, louvers, vent pipe openings, and any other openings). Sand cement may be used opposite intervals of existing cementitious annular seals and must be used from ground surface to 50 feet MD. Bentonite should not be added to the cement mix as the resulting increase in viscosity will impede the complete saturation of gravel pack with sealing material.

Wells with a diameter of 3 feet or more may be filled with concrete opposite intervals of existing cementitious annular seals (i.e., not screened intervals) to ground surface (See Section 5.9.2.4 Concrete).

5.4.2. Placement of Sealing Materials

Section 5.9 Approved Sealing Materials may be used in the destruction of cement-sealed wells as follows. Neat cement must be used as the sealing material in all sections of the well structure with existing perforations (e.g., screens, louvers, and any other openings). Sand cement may be used opposite intervals of existing cementitious annular seals and must be used from ground surface to 50 feet MD. Bentonite should not be added to the cement mix as the resulting increase in viscosity will impede the complete saturation of gravel pack with sealing material.

Wells with a diameter of 3 feet or more may be filled with concrete opposite intervals of existing cementitious annular seals (i.e., not screened intervals) to ground surface (See Section 5.9.2.4 Concrete – “Concrete for Destruction of Large Diameter Wells”).

5.5. Destruction of Drilled GHEWs

The following is required for the destruction of vertically, inclined, and HDD drilled GHEW loops.

5.5.1. Approved Sealing Material

Any grout material meeting the following two criteria may be used for GHEW destruction:

- 5.1. Meets NSF/ANSI Standard 60, Drinking Water Treatment Chemicals – Health Effects, or NSF/ANSI Standard 61, Drinking Water System Components – Health Effects.
- 5.2. Is mixed and cured according to the manufacturer’s or developer’s specifications to achieve a hydraulic conductivity of less than or equal to 1×10^{-7} centimeters per second using a standard permeameter test as described in ASTM D5084, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*.

5.2.1.1. Exposing and Severing Ground Loops

The connection of the ground loop casings to the header assembly must be exposed by excavation and the casings cut off at the bottom of the excavation.

5.2.1.3. Sealing Ground Loops

Each ground loop casing must be completely sealed by pumping seal material into one end of the ground loop until undiluted seal material returns are observed flowing from the other end.

The connection between the ground loop and the GHEW pump/heat exchange equipment must be severed at the equipment. Enough sealing material must be pumped into the pipe to seal 20 feet of the pipe leading away from the pump/heat exchange equipment and into the loop field.

Seal material must be allowed to set for 24 hours before topping off with seal material as necessary before backfilling.

5.2.1.4.Backfilling

The excavation must be backfilled according to Section 7.7 Backfilling Excavations for GHEW.

5.2.6. Destruction of Excavated GHEWs

The following is required for the destruction of horizontal GHEW ground loops constructed by excavation.

5.2.6.1. Approved Sealing Material

Any grout material meeting the following two criteria may be used for GHEW destruction:

- 3) Meets NSF/ANSI Standard 60, Drinking Water Treatment Chemicals – Health Effects, or NSF/ANSI Standard 61, Drinking Water System Components – Health *Effects*.
- 4) Is mixed and cured according to the manufacturer’s or developer’s specifications to achieve a hydraulic conductivity of less than or equal to 1×10^{-7} centimeters per second using a standard permeameter test as described in ASTM D5084, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*.

1)2. Sealing the Loop Field Connection

The connection between the ground loop and the GHEW pump/heat exchange equipment must be severed at the equipment. Enough sealing material must be pumped into the pipe to seal 20 feet of the pipe leading away from the pump/heat exchange equipment and into the loop field.

5.3. Topping Off and Surface Completion

In unconsolidated materials, a hole must be excavated around the well casing and conductor casing, if present, to a TVD of 5 ± 1 feet below the ground surface and the casings removed to the bottom of the excavation.

The sealing material must be allowed to spill over into the excavation to form a cap. The presence of the cap must be checked after sealing material has set. Any void space created by sealing material dropping into the hole before setting must be topped off with sealing material to, again, spill over into the excavation and form a cap (**Figure-13**).

After the well has been properly sealed, including sufficient time for sealing material in the excavation to set, the remaining excavation must be backfilled and compacted (as applicable) commensurate with the planned use of the site. The hydraulic conductivity of the fill must be approximately equal to, or less than, the adjacent soil.

5.4. Exception for Wells with a Diameter Exceeding 5 Feet

Native fill or fill dirt may be placed from the ground surface to a TVD exceeding 5 feet but no deeper than the diameter of the hole to be filled. The native soil or fill dirt must contain at least 10 percent clay and must be compacted to at least 90 percent relative compaction.

REFERENCES

Note to TAC: This list is incomplete.

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Latorre CA, Wakeley LD, Conroy PJ. 2002. *Guidelines for Installation of Utilities Beneath Corps of Engineers Levees Using Horizontal Directional Drilling*. United States Army Corps of Engineers Engineer and Research and Development Center. Geotechnical and Structures Laboratory. ERDC/GSL TR-02-9.

APPENDIX A. Information and Investigations to Support Variance Requests

The LEA may require the following, or other, information, testing, and analysis be submitted to consider a variance request.

- Geologic Log – Geologic logs prepared by a Professional Geologist according to the Unified Soil Classification System or ASTM D 2488 – Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).
- Downhole Geophysical Surveys – Downhole geophysical surveys should at a minimum include resistivity (single point, short, and long), spontaneous potential, and natural gamma surveys
- Geologic Cross Section(s) – Cross sections will include detail sufficient to identify aquifers where well screens will be placed, aquifers penetrated but not screened, and confining layers
- Drinking Water Source Assessment and Source Protection (DWSAP) document
- Groundwater level measurements, seasonal and/or long-term water level trends
- Groundwater gradient and direction
- Available water quality data
- Well construction details with As-Built diagram
- Aquifer testing data

APPENDIX B. Groundwater Information Resources

Following is a list of statewide information resources that may be useful in assessing site hydrogeologic conditions. This list is a starting point and is not intended to be exhaustive. Some data are subject to restrictions and may not be available to the public.

In addition to statewide sources, hydrogeologic information may be available from local sources. LEAs may be consulted regarding availability of local sources of such information.

California State Geoportal

Township, Range, Section

<https://gis.data.ca.gov/datasets/2b43d73d12664b73943478741dc5dbf4/explore>

California Department of Water Resources

California Statewide Groundwater Elevation Monitoring (CASGEM) Program

Under the CASGEM Program, DWR maintains a database of groundwater elevation monitoring data for all of California's alluvial groundwater basins, which are collected and reported by local entities and made available to the public through DWR's website. The CASGEM online system includes a map-based graphical interface for access to well locations, groundwater elevations, well depths, and screened intervals. Well depths and screened intervals are only available for wells designated as CASGEM wells.

California Water Data Library (WDL)

The WDL is an online, map-based user interface that provides access to groundwater elevation data for CASGEM wells, non-CASGEM wells, and historical wells. WDL also provides integrated access to other types of hydrologic data, including surface and groundwater quality, streamflow, and land subsidence.

Groundwater Information Center (GIC)

DWR's Groundwater Information Center (GIC) is a website that provides access to groundwater-related data, reports, and other information. The GIC Interactive Map is a web-based application that enables viewing and downloading groundwater-related geospatial data or geographic information system (GIS) layers. Selected groundwater elevations, subsidence data, basin prioritization, and Bulletin 118 basin boundaries are available through the Interactive Map.

Well Completion Reports

DWR is responsible for maintaining a repository of all well completion reports in the state. The well completion reports are records on well construction, rehabilitation, and destruction, which include information such as the well location, geologic log, screen intervals, and annular seal.

<https://water.ca.gov/Programs/Groundwater-Management/Wells/Well-Completion-Reports>

SGMA Data Viewer

<https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#currentconditions>

State Water Resources Control Board

GeoTracker GAMA – Groundwater Ambient Monitoring & Assessment Program

The GAMA Program is California's comprehensive groundwater quality monitoring program administered by the State Water Resources Control Board and available at the State Water Resources Control Board's website. GeoTracker GAMA is an online groundwater

information system that integrates groundwater quality data from the GAMA Program with data from several other agencies including DWR, California Department of Public Health, California Department of Pesticide Regulation, and the United States Geologic Survey (USGS). Data compiled in GeoTracker GAMA are searchable by chemical or location with results displayed on an interactive Google maps interface.

California Department of Toxic Substances Control

EnviroStor Data Management System

EnviroStor Data Management System is a public website that provides detailed information on inspections and enforcement actions of permitted hazardous waste facilities, as well as site investigation and cleanup projects overseen by California Department of Toxic Substances Control. Users can conduct searches using various criteria, including facility/site name, address, city, and county.

FEMA's National Flood Hazard Layer (NFHL) Viewer

The National Flood Hazard Layer (NFHL) dataset represents the current effective flood data for the country, where maps have been modernized. It is a compilation of effective Flood Insurance Rate Map (FIRM) databases and Letters of Map Revision (LOMRs). The NFHL is updated as studies go effective. For more information visit FEMA's Map Service Center (MSC).

[https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?](https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd)

[id=8b0adb51996444d4879338b5529aa9cd](https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd)

U.S. Geological Survey

National Water Information System (NWIS)

The USGS National Water Information System (NWIS) contains extensive water data for the nation, including groundwater. Public access to NWIS is provided through the USGS Water Data for the Nation website.

APPENDIX C. Field Guide for Logging Water-Well Boreholes (Hanna 2004)

PLACEHOLDER Pending DWR Approval

See Plenary 3 Slide 61 for Sample Image: <https://cadwr.box.com/s/bqakzj05azn2du9u2heckrdhmxewcnn5>

APPENDIX D. Geophysical Methods to Detect Annular Seal

The following geophysical surveys can be used to detect the location and identify annular seal material behind a well casing. It is recommended that before utilizing any survey method or methods that a professional geophysical services company be consulted regarding the applicability to the well to be investigated.

- Cement Bond Log
- Temperature Survey
- Noise Log
- Gamma Ray Log

Additional Input Requested from TAC to correct/complete the information below for use with Appendices A and D

| Log type | Specific log | Borehole Conditions | Casing Material(s) | Sealing Material(s) | Information |
|-----------------|--|---|--------------------|---------------------|---|
| Nuclear | Gamma-ray Spectral gamma-ray Gamma-gamma (density) Neutron-neutron (porosity) | Open and cased holes with or without fluid Open holes with fluid | | | Presence of seal, Lithology, density, porosity, calibration of surface geophysics |
| Electrical | Self-potential Resistivity Focused Resistivity | Open or screened holes with fluid | | | Lithology, calibration of surface geophysics, location of pvc screens |
| Electromagnetic | Induction Susceptibility | Open and pvc cased holes with or without fluid | | | Lithology, saline waters |
| Acoustical | Sonic | Open holes with fluids | | | Lithology (porosity) |
| Physical | Caliper | Open and cased holes with or without fluid | | | Borehole diameter |
| Optical | Borehole camera Optical borehole viewer | Open and cased holes with clear water | | | Casing or borehole condition, caving, slope and aspect of fractures and layers |
| Flow | Impeller flowmeter Heat pulse flowmeter | Open and cased holes with fluid | | | Vertical water movement in the borehole |
| Fluid | Water quality | Open and cased holes with fluid | | | EC, temperature, pH, O ₂ , NO ₃ , Eh, total gas pressure |

APPENDIX E. Cathodic Protection Well Basics

Most wells in California are constructed to extract groundwater, inject water, or monitor groundwater conditions. Other, less common types of wells include cathodic protection wells. Cathodic protection wells, called 'ground beds,' or 'anode ground beds' house cathodic protection anodes to mitigate corrosion of metallic pipelines, tanks, and other metallic facilities that may be submerged in water or buried in or in contact with the ground or soil. The ground beds may be shallow (<50 feet deep) or deep (>50 feet to 1,000 feet or more). AC mitigation and grounding wells are similar to cathodic protection wells in terms of their design. However, they serve different purposes and are not included in the California Water Code's definition of a cathodic protection well.

Corrosion

Corrosion is defined as the deterioration of metallic objects by electrochemical reaction with the environment. The corrosion process is illustrated in Figure 1 for a metallic pipeline in soil. This process gradually weakens the pipeline by reducing the wall thickness and can cause its failure.

In Figure 1, current, in the form of ions, is shown flowing through the soil from the anode area, where the positive metal ions enter the soil, to the cathode area. Similar to a simple circuit, this ion transfer current is balanced with conventional current flow, through the metallic pipe, from the cathode area to the anode area. The ion exchange occurs as a result of variations in the pipe material and variations in the soil, such as salt concentrations, heterogeneous soil types, differing moisture contents or differing oxygen concentrations. Corrosion occurs at the anode where the current, or metal ions, leave the pipe surface into the soil.

Cathodic Protection

"Cathodic protection" is a term used to describe a system designed to proactively prevent or minimize corrosion of buried or submerged metallic equipment and structures. A cathodic protection system is designed to force the entire buried structure to become a cathode, eliminating all anode areas on the surface of that structure, and therefore preventing or reducing corrosion. This is accomplished by introducing a component called a cathodic protection anode, that is intended to discharge current to the buried structure and corrode in place of the buried metallic structure, as shown in Figure 2. The protected structure is made to be a permanent cathode thus, the structure is said to be "cathodically protected."

Cathodic Protection Wells

California Water Code Section 13711 defines a "cathodic protection well" as an anode installation exceeding 50 feet in depth. Installations that are 50 feet deep or less are considered "shallow anodes", not cathodic protection wells. Cathodic protection wells are widely used to prevent corrosion of metallic objects in contact with the soil. Such objects include petroleum, natural gas, and water pipelines, and related storage and production/processing facilities. They may also be used to prevent corrosion failure on conduit or grounding grids used for power lines, telephone cables, and switchyards. Cathodic protection wells are sometimes used to control corrosion in large water, gas, and oil production wells.

Shallow anode installations are not subject to the provisions of the Water Well Standards, however if a local enforcement agency desired, these standards could be similarly applied to shallow anodes as well. In all cases, cathodic protection, wells regardless of depth, should not contaminate groundwater through poor construction methods, poor well design, or failure of materials.

Per the guidance provide in 49 CFR Parts 192 and 195, cathodic protection, along with active monitoring, must be implemented to mitigate corrosion on pipelines that transport gas or other "hazardous" gases and liquids. Along with the CFR, the Natural Gas Pipeline Safety Act, Public Law 90-481 adopted by Congress in August 1968, provides requirements for cathodic protection of certain pipelines, and cathodic protection is supported by the CaDOT Corrosion Guidelines and Title 23 of the California Code of Regulations.

Design and Construction of Cathodic Protection Wells

There are many configurations for cathodic protection anode ground beds. One of the more common designs is illustrated in Figure 3. Cathodic protection wells may be constructed by:

1. Drilling a 6- to 12-inch diameter borehole to a desired depth (10-inch is the current industry standard). Cathodic protection wells normally range from 100 to 500 feet in total depth. Depending on soil type and the depth of the groundwater, wells have been drilled to depths of over 800 feet.
2. Placing a surface casing, as needed, to stabilize the borehole in unstable soil conditions or if the well is drilled at an angle.

3. Placing a string of anodes in the borehole within a designated interval, usually referred to as the "anode interval" or "active zone". The anode depth and spacing may be as originally designed, or if the well was logged for soil resistivity, the depth and spacing may be adjusted to optimize the current output of the ground bed. For wells drilled in environmentally sensitive areas or where aquifers should not be allowed to communicate, anodes should be designed to be placed either above or below the aquifers to prevent cross contamination.
4. Installing vent pipe at the same time the anodes are installed. The vent pipe, typically 2-inch perforated PVC pipe, is lowered with the anodes. The vent pipe extends to ground surface, however, is only perforated in the anode interval. The purpose of the vent pipe is to release gases generated from the operation of the anode ground bed. The vent pipe is terminated above ground with a gooseneck, or "U" bend, to allow for the gases to escape, while preventing water from entering the well.
5. Backfilling the anode interval around the anodes with an electrically conductive material. The backfill traditionally used is commonly known as "coke, coke breeze, or calcined petroleum coke backfill" in the industry. Coke breeze commonly consists of either coarse grained materials, designated as equivalent to a 1/8" x 3/8" sand mixture or a "6 x 12" sand gradation, and finer grained materials with the consistency of "silica sand."
6. Sealing the annulus between the vent pipe and the borehole wall, from the top of the conductive 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 structure to be protected, through a direct electrical current source (such as a rectifier).

Drilling depth should be planned as to avoid artesian conditions (such as penetrating through a confining clay layer). The vent pipe can act as a casing for artesian flow that might be very difficult to shut off. This condition could result in uncontrolled flow that causes waste and may become a public nuisance. If artesian conditions are perceived to be present or encountered, two or more shallower cathodic protection wells or the use of ventless anodes in conductive concrete should be considered.

Any information that can be provided to the well driller by the LEA at the time of permit issuance regarding special conditions or advisory's (flowing artesian conditions, known confining layers, contaminated or polluted aquifer zones) in the vicinity of the planned well is extremely helpful to the well driller.

Shallow Anode Considerations: Shallow anodes not regulated by the Water Well Standards (≤ 50 feet deep) may have similar construction and sealing features or requirements as wells more than 50 feet deep. However, some shallow anode designs do not require anode vent pipes. In the case where the well is 20 feet deep or less, it is

common to entirely backfilled with screened native material between the conductive backfill and the ground surface. LEA's should advise a seal depth and permit requirements for shallow wells.

Individual designs of cathodic protection wells vary, and if an "unconventional" well design is proposed (particularly a design that does not facilitate eventual destruction of the well such as an anode vent pipe less than 2" diameter), permission for its installation should be decided on a case-by-case basis by the LEA. Cathodic protection wells that can eliminate the vent pipe is an acceptable alternative so long as the well was an approved design with a full seal. In this case well destruction in the future may not be required.

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 typically designed to last 15 to 20 years, however, depending on the current output of the Cathodic Protection system, they can last over 50 years.

Some cathodic protection wells are constructed with large diameter vent pipes so that anodes can be replaced through the vent pipe. Anode replacement through the vent pipe eliminates the need to drill replacement wells when anodes have been expended. When the replaceable anode design is suggested, permitting agencies should confirm that the sealing requirements between the active column and the surface are met.

Need for Cathodic Protection Well Standards

The goal of the well standards is not to ensure that cathodic protection wells provide protection to its intended structure, but rather to protect groundwater.

Improperly constructed cathodic protection wells can allow groundwater 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 are particularly conducive to the movement of poor-quality water, pollutants, or contaminants and should not be allowed. Additionally, to properly destroy existing cathodic protection wells constructed with gravel backfill, the gravel should be drilled out to a minimum depth and sealed with approved sealing materials as described in the current standards.