Summary of Well Completion Issues and Analysis

Prepared by:
Pastor, Behling, & Wheeler, LLC

Prepared for:
Victoria County Groundwater Conservation District

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SECTION 1 - INTRODUCTION

The Victoria County Groundwater Conservation District, in response to concerns expressed about District Rules by the well-drilling community, initiated task order PBW-1. The scope of PBW-1 is:

PBW will provide technical support to the District regarding possible Rule revisions related to well completion. PBW will perform the following general activities:

- Review the District's current rules regarding and well completion (e.g., cementing and surface completion requirements) and well spacing (to the extent they relate to well completion and distances from sources of contamination);
- Review State of Texas rules related to same (if any);
- Review State of Texas Well Reports and associated drillers logs for wells in Victoria County; summarize findings related to surficial geology and surface completions;
- Perform literature review of pertinent technical issues (e.g., NGWA Groundwater Online);
- Provide technical input to General Manager and Board regarding potential rule revisions;
- Attend meetings, as necessary.

These activities have been completed. This report documents PBW's findings regarding the well construction standards and spacing requirements.

SECTION 2 - SEALING OF THE ANNULAR SPACE

DEFINITION: Sealing of the annular space consists of the filling of the annular space between the casing and the geologic formation, from the surface to a depth above or to the producing zone. For the purposes of this report, the term "well sealing" is interchangeable with "grouting".

OBJECTIVE OF THE SEAL: The principal reasons for sealing a well are (1) protection of the groundwater resource from the surface and/or subsurface contamination, (2) sanitary protection of the water supply, (3) protection of the casing from external corrosion, and (4) preservation of the hydraulic characteristics of an artesian aquifer.

PRIMARY ISSUES:

1) What should be the depth of the seal? Annular seals extend from the surface to a certain prescribed depth. Currently, the District rules require the seal to extend to 100 feet below the surface in all situations. The State of Texas requires only 10 feet in most situations. Should the District revise their rules to a more appropriate depth?

2) What material should be used as a sealant? The District rules currently specify "cement grout or bentonite slurry". Research has shown that some well sealing materials are preferable in certain situations (e.g., high-solids bentonite grout and hydrated bentonite chips and pellets appear to yield intact seals if placed properly) (Christman, M.C., et al, 2002). In general, while the hydraulic conductivity of the sealing material is important, the final success of the sealant depends on its structural ability under the given subsurface conditions (i.e., degree of saturation, presence of unconsolidated sediments that promote caving into the annular space, etc.) (Edil, T. B., et al., 1992). Also, some sealing materials do not adhere to PVC or steel pipe (e.g., Portland cement, typical cement-bentonite slurries), while others do (e.g., Benseal bentonite slurry) (Edil, T. B., et al., 1992). Finally, research has also indicated that drilling mud (bentonite slurry) may not provide a good seal when used as an annular sealant (Edil, T.B., 1992).
3) What should be the method of placement of the annular seal? For instance, where the grout is to be placed under water or where the annular space to be sealed is not easily accessible from the surface, positive emplacement of grout by tremie, pumping, or pressure is recommended (NGWA, 2009). Also, issues such as the size of the annular space, the use of centralizers, proper mixing of the grout, etc., also play a role in the selection and placement of an effective annular seal (Anderson and McClain, 2007).

GENERAL CONCEPTS:

1) In determining the grouting requirements for a specific well, consideration must be given to existing surface conditions, especially the location of potential pollution sources, and to subsurface geologic and hydrogeologic issues (Anderson and McClain, 2007).
2) Several critical issues impact the design and ultimately the success or failure of an annular seal. The lithology (presence of clay/sand layers), degree of saturation in the subsurface interval to be sealed, the water chemistry, and the location of potential pollution sources are key factors to consider.
3) Given the above concept, the process for designing a seal may be achieved using a systematic process in order to reach the objective. The process involves (1) pre-planning; (2) effective drilling operations, and (3) efficient zonal isolation.
4) The last two steps in the process above are generally up to the driller once a design has been established. The first step is the most difficult to address.
5) State of Texas requirements clearly do not fit all situations and can be considered the minimum requirement for sealing the annulus. In that sense, protection of aquifer, in the context of annular sealing, should consider local geology and hydrogeology.
6) Even though there is general agreement that subsurface conditions are the most important factor for designing the depth of the annular seal, it is a fact that the annular seals in wells in Victoria County rarely exceed 15 feet. In other words, no matter what the geologic conditions encountered, the drillers install an annular seal to a maximum depth of 15 feet.

7) The geology of Victoria County allows for some flexibility with regard to the requirements for sealing (and the distance of water wells from sources of contamination). This flexibility is primarily afforded by the typical presence of significant clay layers (confining layers with low hydraulic conductivity and at least 5 feet thick) in the upper 100 feet (or more), or alternating clay and sand layers within the upper 100 feet. The presence of clay layers precludes the downward migration of potential sources of contaminants from the near-surface to the zone of production. After drilling a well bore, well sealing is required to prevent migration of contaminants along the borehole wall. Furthermore, Victoria County lacks other subsurface conditions that affect the adequate annular sealing of wells, such as (1) widespread and interconnected fracture or fault zones, (2) highly mineralized sections, (3) zones of extreme porosity and permeability, (4) lignite or coal seams, and/or (5) widespread zones of contamination by anthropogenic or natural sources (i.e., salinity) in the subsurface interval above the zones of production.

RECOMMENDATION:

1) Revise required annular seal depth between 30-50 feet. Justification: Based on a review of driller's logs from the entire county, it is rare that a significant confining layer (i.e. a clay layer of at least five feet thick) is not present in the upper 30-50 feet[1]. However, there are instances where the upper 20-30 feet is predominantly sand (based on drillers logs), and for which a 15-foot seal would not adequately protect the interval below 15 feet to the next packer or to the producing zone, assuming the hole has not collapsed on itself (and there is disagreement as to the extent that the open portion of the borehole collapses on itself when the borehole is adjacent to clay strata). Sealing the annular space to this depth will provide adequate protection of the resource by limiting the potential for contaminants to migrate through thick surface sands (when they are present) and reach un-sealed annular space above the zone of production.
    a. Alternative Recommendation to No. 1: Provide schedule for drillers to consult for sealing requirements depending on the geologic conditions observed. For instance, a table that correlates observed subsurface conditions with a required depth for annular seal.

2) Add the following exclusion: The annular sealing depth requirement may be reduced to the interval from the surface to the depth of the first potable water-bearing strata, if the well is targeting that interval for production, but at a minimum the surface annular seal shall extend to a depth of at least 10 feet.
3) Do not designate certain methods or materials for placement of annular seals (with the exception in No. 5 below). In my opinion, there is not satisfactory agreement within the well-drilling or scientific community regarding the appropriate methods or materials to be used for annular seals in all cases (and as noted above, methods and materials should be chosen based on the

[1] Drillers logs are based on cuttings that return to the surface from the borehole and also on a drillers professional judgment of downhole conditions while drilling.

observed subsurface conditions). Rather, strengthen the language in the District's Rules regarding the selection of appropriate methods and materials and protection of the resource. (See No. 4 below)

4) Strengthen language within the District's Rules regarding the prohibition against degradation of the resource and the obligation of the driller to protect the resource. Suggested language could include:
    a. The driller shall use appropriate methods and materials in constructing a well in order to minimize the potential for contamination of the County's groundwater resources.
    b. All new wells, both exempt and non-exempt, shall be constructed to prevent the commingling of waters of different chemical quality and prevent the degradation of any aquifer or zone of potable water.
5) Revise the District Rules to
    a. specify that annular seal material should be a neat cement grout, bentonite-cement grout, high-solids bentonite grout, bentonite slurry, or bentonite chips/pellets;
    b. restrict the use of drilling mud (bentonite slurry) to seal the annular space. ; and
    c. require that the well casing be centered in the well bore prior to emplacing the seal and that the emplacement result in a seal that is absent of significant voids.
6) Revise well application forms to include information on anticipated lithology in upper 100 feet and expected seal requirement that will be protective of the resource.
7) Develop program for investigation of well installation and enforcement of the District's well completion rules.
8) Consider adding a requirement for an access tube to allow for measurement of water levels or disinfecting the well.

SECTION 3 - SURFACE COMPLETION REQUIREMENT

DEFINITION: A surface completion for a well typically consists of (1) a concrete well pad, sealing block, and/or sleeve; (2) a portion of well casing extending above ground level; and (3) a sanitary seal (e.g., a well cap).

OBJECTIVE OF THE SURFACE COMPLETION: The primary purposes of the surface completion are to: (1) protect the groundwater resource and the water in the well; (2) provide protection of the above-ground components of the well from damage by vehicles, mowers, cattle, etc.; (3) provide additional protection of the annular space from contaminants that may infiltrate from the surface; and (4) provide access to the well.

PRIMARY ISSUES:

1) What is an appropriate surface completion in the context of protection of the aquifer? Is a concrete pad any more protective of the aquifer than a sleeve that is appropriately cemented into place?

GENERAL CONCEPTS:

1) Assuming an appropriately constructed annular seal and sanitary seal, the concrete pad, block or sleeve primarily provides protection of the well, not the aquifer. The annular seal and sanitary seal provide for the protection of the aquifer and of the well water.
2) A concrete pad in some situation makes it difficult to access the well for maintenance, as any vehicle would have to maneuver around the pad. Damage to the pad may result.

RECOMMENDATION:

1) Allow sleeves in addition to concrete pads or blocks for domestic wells (exempt wells).
2) Add language regarding the requirement for installation of a sanitary seal.
3) The District Rules could be revised as follows to address No. 1 and No. 2 above:
    a. All wells shall have a concrete slab, sealing block or sleeve above the annular seal and around the well at the ground surface.
    b. If used, a slab or block shall extend at least two (2) feet from the well in all directions and have a minimum thickness of four inches and shall be separated from the well by a plastic or mastic coating to prevent bonding of the slab to the casing.
    c. Regardless of the use of a slab, block or sleeve, the ground surface shall be sloped to drain away from the well.
    d. In all wells:
        i. The casing shall extend to a minimum of one foot above the original ground surface; and
    e. A water tight sanitary seal (well cap) shall be installed at the top of the casing for all water wells to prevent the entrance of contaminants into the well. Sanitary seals should be constructed of durable material. If any opening is made to the sanitary seal for the purposes of venting, electrical conduit, etc., the opening should be made water tight.
4) Strengthen language regarding the prohibition against degradation of the resource and the obligation of the driller to protect the resource (see No. 4 in Section 1, Recommendations).

SECTION 4 - DISTANCE FROM WELL TO SOURCES OF CONTAMINATION

DEFINITION: There must be some requirement for limiting the distance between a source of contamination and a water well to preclude the contamination of the well. In this discussion, we will primarily consider the source of contamination to be a septic system tank or drain field.

OBJECTIVE OF THE SEPARATION BETWEEN A WELL AND A SOURCE OF CONTAMINATION: The primary purpose for providing a separation between a water well and source of contamination is to limit the risk of contaminants migrating through either the subsurface strata between the bottom of the tank/drain field and the zone of production or through the subsurface strata to the unsealed annular space above the zone of production.

PRIMARY ISSUES:

1) District Rules currently require a new well to be located at least 100 feet from a source of contamination such as a septic system tank or drain field.
2) State rule allows for a minimum separation of 50 feet if the annular seal of the well extends to 100 feet depth.
3) The District's rules regarding well placement including the 50-foot property line spacing requirement) substantially limit the development of small properties and may be overly protective and unnecessarily burdensome to these property owners.
4) In the meeting where the drillers voiced opposition to the new rules, they acknowledged that the rule requiring 100 foot of annular seal when near a septic drain field was not overly burdensome.

GENERAL CONCEPTS:

1) Problems with groundwater contamination by septic systems are usually found in areas where shallow groundwater (say, less than 50 feet) is used for water supply and in geologic environments that are conducive to rapid recharge (karst, glacial, alluvium). Although there are some shallow water supplies in Victoria County, most are at greater depth (greater than 100 feet). Furthermore, karst and glacial environments are not found in Victoria County, and there are only a limited number of wells installed in alluvial deposits.
2) Septic systems, if properly installed and maintained, are designed to limit the amount of contaminants (i.e. fecal coliform) that leave the system.
3) The presence of alternating clay and sand layers in the upper 50 feet of the surface across much of Victoria County should generally preclude the downward migration of contaminants to deeper aquifers via natural processes (i.e., exclusive of contamination via a poorly or inappropriately sealed well). Also, bacteria would tend to be naturally attenuated (filtered) by the materials along the flow path, or would die due to long travel times and lack of nutrients/oxygen.
4) A requirement to seal the well to 100 feet should adequately protect the well from migration of contaminants to unsealed annular space and potential exposure to the producing zone when a well is within 100 feet of a potential source of

contamination such as a septic system. In other words, the contaminants would have to travel through multiple clay layers to reach a portion of the well that has no annular seal.

5) In most geologic environments in Victoria County, it is unlikely that contaminants would migrate to the unsealed annular space of a well with annular sealing to 100 feet and being offset by at least 50 feet horizontally. This assumption is based on a general knowledge of subsurface stratigraphy in Victoria County and the fundamentals of contaminant transport, but is not tested by modeling or empirical data.

RECOMMENDATION:

1) Allow for new wells to be located closer than 100 feet to septic drain fields per State rule as long as the annular seal extends to 100 feet.
2) Strengthen language regarding the prohibition against degradation of the resource and the obligation of the driller to protect the resource (see No. 4 in Section 1).
3) Add fecal coliform bacteria and nitrogen compounds to list of potential constituents of concern for groundwater quality monitoring program and gain a better understanding of current septic-related contamination issues in Victoria County.
4) Recommend that well is uphill of septic system if at all possible.

SECTION 5 - RECOMMENDATIONS FOR PROCESS TO REVISE RULES

1) Develop revised rule language.
2) Develop process of working meeting(s) with stakeholders to arrive at set of requirements that is appropriately protective of the aquifer and acceptable to stakeholders.
3) Revise rules per outcome of working meeting(s).

SECTION 6 - REFERENCES

Anderson, E., and T. McClain. 2007. Finding Success. *Water Well Journal*, May.

Christman, M.C., C. H. Benson, and T. B. Edil. 2002. Geophysical Study of Annular Well Seals. *Ground Water Monitoring and Remediation* 22, no. 3, Summer, pp. 104-112.

Edil, T.B., M.C. Chang, L.T. Tan, and T.V. Riewe. 1992. Sealing Characteristics of Selected Grouts for Water Wells. *Ground Water*, Vol. 30, No. 3, May-June, pp. 351-361.

National Groundwater Association (NGWA). 2009. Grouting of Water Wells. http://www.ngwa.org/govaffairs/statements/issgrout.aspx.

ATTACHEMENT 1 - SUMMARY OF RULES RELATED TO WELL COMPLETION, SOURCES OF CONTAMINATION AND WELL SPACING

ITEM	RULE TYPE	RULE SOURCE AND CITATION		DIFFERENCES BETWEEN VCGCD AND STATE OF TEXAS RULES AND COMMENTS
		VCGCD	State of Texas	
1	Well Completion - Annular Seal (See Also Item 3)	**Annular space between the borehole and casing shall be filled from ground level to the top of water bearing strata or 100 feet below land surface or well head with cement slurry or bentonite grout. (Rule 8.3.1)**	**Annular space to a minimum of ten feet shall be filled from ground level to a depth of not less than 10 feet below ground surface or well head with cement slurry, bentonite grout or eight feet solid column of granular sodium bentonite topped with two feet cement atmospheric barrier. (Rule 76.1000(a)(1))** For wells less than 100 feet deep, the cement slurry, bentonite grout or bentonite column shall be placed to the top of the producing layer. (Rule	**VCGCD requires 100 foot annular seal in all wells.** **State of Texas rules generally require only 10-foot annular seal. State of Texas only requires 100-ft seal when within 50-feet of a source of contamination.**