EVALUATION OF MINIMUM WELL SEAL DEPTH IN IDAHO

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INTRODUCTION

Ground water is one of the most important natural resources within Idaho. More than 90 percent of municipal and domestic water supplies are obtained via wells. Protection of ground-water quality is an important aspect of long-term use of ground water within Idaho. Protection of ground-water quality is at least a two part process. First, we must eliminate or limit the surface or near surface contamination sources to the maximum extent possible. Second, we must make sure that the low hydraulic conductivity zones that overlie most aquifers are not compromised by water wells that have inadequate surface seals.

The purpose of this report is to present an analysis of the 2009 revision to the Idaho well construction standards that requires that a surface seal be installed to a minimum depth of 38 feet below ground surface in all new water wells except for the Rathdrum Prairie aquifer. Installation of a surface seal as part of the well construction process is important because the borehole created during well construction has the potential to provide a preferential pathway for downward water movement from contaminant sources at land surface and near land surface to underlying aquifers, both shallow and deep.

Questions were raised during the 2013 legislative session relative to the appropriateness of requiring all new wells outside of the Rathdrum Prairie aquifer to be constructed with a minimum seal depth of 38 feet, particularly in northern Idaho. This report has been prepared under contract with the Idaho Department of Water Resources (IDWR) in part to respond to those questions.

HYDROGEOLOGIC SETTING

Water wells have been constructed in all portions of Idaho where people live. Idaho is blessed with extensive ground-water resources because of the geologic setting and climate of the state. Seventy major water aquifers were identified in Idaho by Graham and Campbell (1981). These range from highly productive ground-water systems hosted in basalt such as the eastern Snake Plain in southern Idaho and the Columbia River plateau in northern Idaho to sand and gravel aquifers such as the Treasure Valley in southwestern Idaho and the Rathdrum Prairie in northern Idaho. Wells have been drilled in all of these identified aquifers. In addition, wells have also been drilled in areas of the state where Graham and Campbell (1981) did not identify aquifers. Many of these areas are mountainous regions where a yield of a few gallons per minute for a domestic well is viewed as a success.

There are three common factors relative to ground-water resources in the wide range of geologic and topographic settings that are found in Idaho. These factors are important relative to analysis of the well seal requirement.

- First, in addition to soil, there are layers of low hydraulic conductivity material overlying most of the aquifers in Idaho. The majority of these low hydraulic conductivity zones consist of sediments rich in silt and/or clay. This material either was deposited in a slow moving stream or lake or represents weathering of rock in place. Other areas are underlain by solid rock that has low hydraulic conductivity. For example, large areas of northern Idaho and portions of southern Idaho are underlain by thick flows of basalt. The centers of individual basalt flows are very dense and have low hydraulic conductivity whereas the flow contact zones have higher hydraulic conductivity values and are the water supply aquifers. The low hydraulic conductivity zones provide protection for aquifer water quality by limiting vertical water movement from the surface into the underlying aquifers.
- Second, the quality of ground water within most areas of the state is excellent. Portions of the state have elevated natural constituents such as arsenic and fluoride but the vast majority of the ground-water resources meet state water quality standards. There are numerous local areas of Idaho where ground-water quality has been degraded because of human activity. In most cases, the contamination sources are at land surface or very shallow in the subsurface. Larger areas of impacted ground-water quality underlie agricultural and industrial areas. Cleanup activities have occurred in specific areas with extreme contamination problems.
- Third, wells constructed with inadequate well seals have and continue to provide an avenue for contaminated water from the shallow subsurface to flow downward into aquifers that are relied on as drinking water sources. Contamination of aquifers in some areas can be linked directly to inadequate sealing of the annular space around casing in drilled wells. An example of this type of problem is described in the following paragraph.

The Idaho Department of Environmental Quality (IDEQ) has identified a ground-water "nitrate area of concern" on the Camas Prairie in northern Idaho. The area includes about 187,000 acres of the plateau north and east of the City of Cottonwood (Mahler and Keith, 2000). The source of nitrate is believed to be from dry land agricultural practices. About 52 percent of wells sampled in the area have nitrate values exceeding 5 mg/l. This is above background levels of about 1 mg/l but below the water quality standard of 10 mg/l. The Camas Prairie area is underlain by relatively flat-lying, thick flows of basalt. The centers of these basalt flows are very dense and thus have very low vertical hydraulic conductivity. One of the primary water-resource problems in the area is the small amount of recharge that occurs to basalt aquifers that are located hundreds of feet below land surface because of the thick, dense basalt flows. The lack of recharge to the basalt aquifers is inconsistent with the presence of elevated nitrate levels in the same aquifers. The nitrate levels in these deep aquifers are difficult to explain without consideration of faulty surface seals in many of the existing wells. I believe that the nitrate found in ground water hundreds of feet below land surface in the Camas Prairie in northern Idaho is present only because of incomplete sealing of the surface casing into dense interior of the uppermost basalt flow in a number of wells.

WELL CONSTRUCTION

The installation of a surface seal is an important component of well construction, regardless of the geologic setting or the drilling method selected. The general steps of well construction using an air rotary or cable tool rig are listed below. The specific steps of construction vary based on site conditions and the type of drilling rig used.

- The first step is the construction of a borehole about 4-inches larger than the pump chamber casing to the target depth of the surface seal. Temporary casing often is placed in the well during this step. For example, 10-inch diameter temporary steel casing typically is placed and/or driven to a minimum depth of 38 feet for a private well that is to be completed using 6-inch diameter permanent casing. The minimum required depth of the surface seal is 58 feet if the well is to be used for a public water supply based on a requirement of IDEQ.
- The second step is the construction of a borehole to accommodate the pump chamber casing (drilling open hole and/or later placing the casing, or drilling and driving the casing) to the final depth of the well. This would be 6-inch diameter casing in the example described above. The final depth of the well typically is based on penetrating sufficient water-producing zone(s) to obtain the target yield.
- The third step is completion of the well opposite the water producing zone(s) with well screen, perforated casing or possibly open hole if the material is stable.
- The fourth step is the installation of the surface seal material around the pump chamber casing as the temporary surface casing is removed. Care must be taken to insure the integrity of the surface seal on all sides of the pump chamber casing.
- The last step is the development and cleaning of the well and test pumping if required.

The selection of the depth of the surface seal should be based on the subsurface geology. Specifically the surface seal should extend into the uppermost low hydraulic conductivity layer that overlies the aquifer, if such a layer is present. However, as described above, the selection of the depth of the surface seal often is the first step of the drilling process. The default for most drillers is to install a seal to the minimum required depth. A driller may recommend a greater depth of well seal if he has experience in the area and understands the subsurface geology. However, given a choice, many well owners will want the minimum surface seal to limit well costs. Most public water supply wells are constructed under the supervision of a qualified engineer, geologist or hydrogeologist. Their bid documents typically specify a well seal depth that will provide the greatest possible protection of the ground-water quality.

A review of well driller reports on file with IDWR provides insight relative to the nature of water wells drilled within Idaho. More than 75 percent of the reports that give information on casing size indicate that 6-inch diameter casing was used. About two-thirds of the more than 166,000 well driller reports on file are for wells drilled to depths of 200 feet or less. These statistics indicate that the majority of wells for which data are available are for small yield uses, dominantly domestic, and are relatively shallow. The locations of wells within the state as sorted by county reflect not only population but the availability of public supply systems. Ada and Canyon Counties each have about 10 percent of the wells within the state, largely because of population. However, Bonner, Kootenai and Twin Falls round out the top five counties with the most wells. Bonner County has a relatively small population but likely has a high number of wells because most of the county is rural.

WELL CONSTRUCTION STANDARDS

The first well construction standards were developed for Idaho in 1970 along with a program to license well drillers. Interestingly, formulation of the standards and licensing of drillers was one of my assignments when I was with the Idaho Department of Water Administration (now the IDWR) from 1967 to 1970. The 1970 well construction standards included a requirement to install a seal around the pump chamber casing to a depth of 18 feet.

Galloway (2007) describes the following history of revisions to the 1970 well construction standards.

- There were significant revisions to the standards in 1975, 1978 and 1988 but no changes relative to the minimum depth of the surface seal.
- IDWR in 2002 awarded a contract with Rocky Mountain Environmental to evaluate the need for new well construction regulations. In 2003, the firm identified the five areas where the well construction standards needed to be improved in order to protect ground-water resources: well sealing, well abandonment, well disinfection, rule clarity and rule enforceability.
- In 2006 and 2007, IDWR utilized the negotiated rule-making process relative to language of new proposed regulations. Twelve meetings were held around the state with an average of 30 people per meeting. Draft revisions of the standards were posted on the IDWR website.

The revised well construction standards rules (IDAPA 37.03.09) were established on May 8, 2009. The key aspects of the 2009 rules relative to the surface seal are listed below.

- *025.07 Use of Approved Sealing Materials and Required Annular Space. Well casings must be sealed in the required annular space with approved material to prevent the possible downward movement of contaminated surface waters or other fluids in any annular space around the well casing….*

- *025.07a All casings to be sealed must be adequately centralized to ensure uniform seal thickness around the well casing. Surface seals must extend to not less than thirty-eight (38) feet below land surface for well depths greater than thirty-eight (38) feet deep…*
- *025.07b Seals are required at depths of greater than thirty-eight (38) feet in artesian wells or to seal through confining layers separating aquifers of differing pressure, temperature, or quality in any well.*
- *025.08bi the extensive (for example, one hundred fifty (150) feet thick or more) unconsolidated, non-stratified, sand and gravel of the Rathdrum Prairie are characterized by extremely high transmissivity and hydraulic conductivity. Under these conditions, sealing wells to depths greater than eighteen (18) feet may not be additionally protective. When a water well is drilled within the boundaries of the Rathdrum Prairie…., well casing must extend to at least five (5) feet below the water table and be sealed to a depth not less than eighteen (18) feet…*
- *025.09a …When artesian water is encountered in unconsolidated formations, the production zone or open interval must be limited to zones of like pressure, temperature and quality… Well casing must extend from land surface into the lower most confining layer above the production zone and must be sealed: from land surface to a depth of at least thirty-eight (38) feet and through all confining layer(s) and a minimum of five (5) feet of seal material must be placed into or through the lower most confining layer above the production zone….or five (5) feet into or through the lowermost confining layer above the production zone and continuously to land surface…*
- *025.09b… When artesian water is encountered in a consolidated formation, well casing must be installed and sealed from land surface to a depth of at least thirty-eight (38) feet; and if the consolidated formation is overlain by permeable formation(s) and water will rise above the consolidated formation, well casing must extend and be sealed at least five (5) feet into the confining portion of the consolidated formation.*

IDWR EVALUATION OF SEAL DEPTH ALTERNATIVES

During the rule making process, the well drilling community in Idaho requested that IDWR consider determination of the required seal depth based on geology. In response to this request, IDWR evaluated the suitability of three alternative well seal depths (18 feet, 38 feet and 58 feet) through an evaluation of a representative number of well driller reports from the IDWR data base. The study was conducted as follows (IDWR, 2008, page 1).

> "Six hundred-ninety-seven (697) drillers' reports from forty-four counties in Idaho were randomly selected from the publically available well log data base and were evaluated to determine the adequacy, based on geology, of the existing minimum requiring eighteen (18) foot surface seal and the proposed thirty-eight (38) and fifty-eight (58) foot seal….

Surface seals based on geology require that a suitable confining layer or consolidated formation is encountered in the bore hole within the interval the seal material is placed. Drillers' reports were used to establish the depth at which the top of the first confining layer or consolidated formation is encountered and their relative thickness.

Of the six hundred-ninety-seven (697) drillers' reports evaluated only two hundred-eighteen (218) encountered the top of the first confining layer or consolidated formation within eighteen feet. Two hundred-thirty-eight (238) wells encountered the top of the first confining layer or consolidated layer below eighteen feet and above thirty-eight feet, and one-hundred-nine (109) wells encountered the first confining layer or consolidated formation below thirty-eight feet and above fifty-eight feet. One hundred-thirty-two (132) of the wells evaluated are currently sealed to depths in excess of fifty-eight feet or would require sealing to greater than fifty-eight feet.

Based on this evaluation, only two-hundred-eighteen (218) of the six-hundred-ninety-seven (697) wells evaluated are effectively sealed within eighteen (18) feet of land surface. By increasing the minimum required seal to thirty-eight (38) feet, an additional two-hundred-thirty-eight (238) wells would be effectively sealed for a cumulative total of four hundred-fifty-six (456). By increasing the minimum seal depth to fifty-eight (58) feet an additional one-hundred-nine (109) wells would be effectively sealed for a cumulative total of five-hundred-sixty-five (565).

Based on geology, only thirty-one percent (31%) of the wells evaluated are effectively sealed within eighteen feet. By increasing the minimum required seal depth to thirty-eight (38) feet, sixty-five percent (65%) of those wells would be effectively sealed, and increasing the minimum required seal depth to fifty-eight (58) feet would benefit eighty-one percent (81%) of these wells."

I reviewed about 100 of the wells used in the IDWR (2008) study and generally agreed with the picks for the top of the confining layer.

RALSTON EVALUATION OF SEAL DEPTH ALTERNATIVES

I conducted a study of well driller reports in 2013 relative to effective seal depths as an independent analysis of the IDWR study. The Ralston study was different from the IDWR in the following ways. First, all of the wells included in the study are all located north of Riggins in northern Idaho. Second, the wells included in the study were selected based on location relative to geologic provinces present in northern Idaho. In most cases, three wells were selected from each township selected to be part of the study with the first well in the top two tiers of sections, the second in the middle two tiers of sections and the third in the lowest two tiers of sections. This procedure was used regardless of whether there were 500 wells or 50 wells within the township. The wells were randomly selected within these set of criteria. The only wells that were excluded from the analysis were those with inadequate information on well completion.

Geologic information included on the well driller reports from 181 wells was evaluated based on whether there was a confining layer above a depth of 18 feet, in the depth range of 18 to 38 feet or greater or at a depth greater than 38 feet. In this way, I judged whether an 18 foot, 38 foot or 58 foot seal would be appropriate. The decision of the appropriate seal depth was easy for about two-thirds of the wells. The decision relative to well seal depth was difficult in the remaining wells mostly because of problems in interpreting the geologic information given (i.e. 0 to 30 feet - clay with sand layers; or 0 to 50 feet - soft and hard layers of basalt).

The results of the Ralston study are as follows. About 50 percent of the wells encountered the first confining layer within 18 feet; about 40 percent of the wells encountered the first confining layer between 18 and 38 feet; and about 10 percent of the wells encountered the first confining layer at a depth greater than 38 feet. In comparison, the IDWR results were 31 percent, 34 percent and 16 percent for the three different seal depths. From a geologic viewpoint, a seal to 18 feet would have been effective for about 50 percent of the wells included in the analysis. A seal to 38 feet would have been effective for about 90 percent of the wells included in the Ralston analysis. The results of Ralston study support the IDWR decision in 2009 to increase the required seal depth from 18 feet to 38 feet.

An additional facet of the Ralston study was to compare the recommended seal depth based on geology to the depth of the seal that was installed based on information from the well driller's report. Only 14 of the 181 wells included in the analysis were drilled during or after 2009.Thus, 92% of the wells were drilled when the minimum seal depth requirement was 18 feet.

A number of the wells included in the study had a surface seal deeper than the recommended minimum.

- About 27% of the wells that I judged to need an 18-foot seal had an installed seal to 38 feet or greater.
- About 26% of the wells that I judged to need a 38-foot seal had an installed seal of 38 feet or greater.
- About 43% of the wells that I judged to need a 58-foot seal had an installed seal of 38 feet or greater.

The data show that a number of drillers in northern Idaho have been installing seals to depths greater than the minimum requirement. The analysis also shows that many of these wells had seal depths greater than the recommended depth based on my analysis of the subsurface geology.

COST ANALYSIS

Construction of a well with a surface seal depth of 38 feet costs more than a similar well constructed with a surface seal depth of 18 feet. The purpose of this section of the report is to provide estimates of the additional cost to the well owner associated with the seal depth rule.

Four drilling firms active in northern Idaho were asked to provide cost information relative to installation of a 38-foot seal versus an 18-foot seal for a 200-foot domestic well. The comparison was based on installation of 6-inch diameter casing which requires that 10-inch diameter temporary casing and/or open hole be constructed to a depth of 18 or 38 feet for the installation of seal material. The costs were given for one or both of the following conditions: 1) only unconsolidated material l (sand, gravel, silt and clay) is encountered in the depth interval of the surface seal - temporary surface casing would be required to a depth of 18 or 38 feet; and 2) consolidated material (solid rock) is encountered in the depth interval of the surface seal - temporary surface casing would be required only to the top of the rock. The drillers provided the cost information with the understanding that they would not be individually identified. Information from the four drilling firms is presented below.

- Driller #1
  - Cost information represents unconsolidated material in the seal depth interval.
  - 20-foot seal would be $520 for drilling plus $350 for the seal material for a total of $870.
  - 40-foot seal would be $1,040 for drilling plus $550 for the seal material for a total of $1,590.
  - The estimated difference in cost between a 20-foot seal and a 40-foot seal in unconsolidated material is $550.
- Driller #2
  - Cost information was not differentiated between unconsolidated or consolidated material in the seal depth interval.
  - Cost of about $600 for an 18-foot seal in a “perfect hole”.
  - Cost of about $1,040 for a 38-foot seal in a “perfect hole.”
  - The estimated difference in cost between an 18-foot seal and a 38-foot seal in a “perfect hole” is $440.
  - Seal costs in difficult circumstances can be $2,500 for a 38-foot seal and half that for an 18-foot seal.
- Driller #3
  - Cost information was given for unconsolidated material in the seal depth interval. Total costs are for a 200-foot well including well cap, permit, PVC screen, 6-inch steel casing and seal.
  - Cost is $9,245 for the well with an 18-foot seal.
  - Cost is $10,065 for the well with a 38-foot seal.
  - The estimated difference in cost between an 18-foot seal and a 38-foot seal is $820. This is about 9 percent of the cost of the well.
- Driller #4
  - Cost information was given for both unconsolidated and consolidated material in the seal depth interval.
  - In unconsolidated material, a well with a 38-foot seal would cost about $1,080 more than the same well with an 18-foot seal.

- In consolidated material, a well with a 38-foot seal would cost about $1,050 more than the same well with an 18-foot seal.

Data provided by four drilling firms from northern Idaho show that the increased cost of a 38-foot seal as compared to an 18-foot seal surrounding a 6-inch diameter steel casing for a domestic well is in the range of $440 to $1,080. One driller noted that the greater seal depth added about 9% to the cost of the well.

WAIVERS FOR THE MINIMUM SEAL DEPTH REQUIREMENT

The well construction rules allow waivers of the minimum standards if approved by IDWR. These waivers provide flexibility in the application of the surface seal requirement in order to respond to unique hydrogeologic environments within the state. Tom Neace of IDWR provided the following summary of the waivers program for 2013 relative to the surface seal requirement.

- 2,149 wells were drilled in 2013
- 28 waivers for sealing requirements were submitted to IDWR in 2013 (1.3% of wells drilled)
- 27 of the waivers were approved

I believe that the waivers program gives IDWR the flexibility to work with drillers for individual wells or specific areas where alternative seal depths would provide adequate protection of ground-water quality.

CONCLUSIONS AND RECOMMENDATIONS

A well that is constructed with a surface seal that does not extend into the uppermost low hydraulic conductivity unit overlying the aquifer has the potential to provide a pathway for contaminants to move from surface or near surface sources into the aquifer. Installation of a well seal is a one-time cost that will provide protection for the aquifer for the life of the well, which can be many decades. In comparison, a poorly constructed seal can allow contaminant transport down along the outside of the casing for the entire life of the well.

The IDWR (2008) study of well driller’s reports in Idaho provides evidence that increasing the depth of the surface seal from 18 to 38 feet provides greater protection for aquifers within Idaho. The Ralston (2013) study of wells in northern Idaho confirms that a minimum seal depth of 38 feet provides considerably greater protection of ground-water quality than does a minimum seal depth of 18 feet.

The one-time difference in cost between an 18-foot surface seal and a 38-foot surface seal is in the range of $440 to 1,080 based on information from four north Idaho drilling firms. One firm estimated the increased cost to be about 9 percent of the total well cost. I believe that this is a reasonable expense for the well owner to have access to the publically owned ground water under his/her property. Also, the deeper seal has direct benefit to the well owner because it decreases potential contamination from the septic disposal system that is typically located on the same property.

The waiver program operated by IDWR provides the opportunity for a shallower seal to be installed in an individual well or in a specific area. The waiver program operated successfully in 2013 and provides a way to adjust the state-wide program to local conditions.

I recommend that IDWR maintain the required seal depth of 38 feet for all wells outside of the Rathdrum Prairie aquifer. I also recommend that IDWR continue to work with the drilling community to identify local areas where the waiver process can be expedited.

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