Case Study: Angular Gravel Packs Lead to Failed Wells

The Yanacocha Mine is located in the Andes Mountains, about 600 kilometers north of Lima, Peru. In order to continue the mining operations, 11 new dewatering wells were installed at the mine in two phases of construction to manage the ground water. When Phase 1 wells were installed (total 5 wells), they were completed as gravel envelope wells. The engineered gravel packs were based on sieve analyses performed on formation materials collected during the borehole drilling. Graded gravel packs were designed and the slot sizes of the louvered well screens were selected to retain the gravel. The Phase 1 wells were highly productive and efficient. The mine managers were very pleased with the results.

When the Phase 2 wells were installed sometime later, the production and efficiency results were dramatically less than those of the Phase 1 wells. Efficient wells exhibit less drawdown and, therefore, they require less power and cost less to operate. When the as-built designs of the Phase 1 and 2 wells were compared, it was discovered that the Phase 2 wells had been constructed with a different type of gravel. Samples of the gravel showed it to be pit run gravel, as used in road construction. It was extremely angular and it had a significant fraction of clay. Neither property was desirable.

As it turned out, it was later found that a purchasing agent at the mine had decided that he could save money for the mine operator by purchasing non-specified gravel at 1/3 the cost of the rounded, select gravel. He clearly did not understand the importance of rounded gravel and made his decision on the cost difference. The mine operator eventually found it necessary to pull out the casing and screen, and reconstruct the wells with rounded, select gravel.

Criteria for Select Gravel Pack

The example above shows the importance of an engineered gravel pack. Gravel pack material should be properly selected to ensure that it exhibits the appropriate physical characteristics that are necessary for optimum performance. Key criteria for gravel packs are as follows:

- Materials should be free of all deleterious substances such as organic matter, silt, clay, and any other objectionable matter.
- It should be water-worn and well-rounded. Well-rounded gravel is less likely to compact tightly, which probably happened at the Yanacocha Mine and caused the loss of production from the dewatering wells. Furthermore, well-rounded gravel forms a more permeable envelope around well screen. This enhances the flow of water to the well.
- It should siliceous material (90 to 95% quartz) that will not dissolve. This is important for wells that are chemically redeveloped with acid. Calcareous (i.e., containing calcium carbonate) material should not exceed 3 to 5% of the total volume; it is readily dissolved by acid.
- The uniformity coefficient of the gravel pack should be 2.5 or less, as recommended by the American Water Works Association. Non-uniform gravel packs are generally favored by most designers.

Installation

The two most common methods of gravel pack installation are: 1) pouring and 2) use of a tremie pipe. For shallow to medium-depth wells, gravel can be poured into the annular space. Periodic surging helps to consolidate the gravel and avoid bridges. When gravel is poured into the annulus it may settle unevenly as heavy pieces of gravel settle more quickly than lighter ones; this creates an unevenly distributed gravel pack.

Installing gravel through a tremie pipe is an effective method of gravel placement that is more likely to avoid bridges and desegregation. As the gravel pack is placed, the tremie is pulled back so that it remains about 40 feet or so above the top of the gravel. Installation with a tremie is made more effective when the gravel is pumped into place with water. The rate of installation is usually about 5 to 10 tons of gravel per hour.

Summary

Gravel pack performs a very important function in water wells. By enveloping the well screen, a properly-selected gravel pack will effectively stabilize the water-bearing formation (i.e., aquifer). In so doing it keeps the borehole wall in place so that fines do not from migrate from the borehole wall towards, pass through the well screen, and then create problems during production pumping.

Selecting gravel pack is a relatively straightforward exercise and there are many gravel pack design methods from which to choose. Virtually all of the methods are based on determining the size range of the aquifer(s) materials. This is accomplished by performing sieve analyses on each aquifer and then using the results to select the appropriate gradation of the gravel pack. Explanations of gravel pack design methods are presented in Technical Memorandum 006-2 and in the *Handbook of Ground Water Development.*

References

- American Water Works Association, 2006, *AWWA Standards for Water Wells (*AWWA A100-06*).*
- Roscoe Moss Company, 1990, *Handbook of Ground Water Development,* John Wiley and Sons, New York, NY.
- _____, 2006, Gravel Pack Design: The Nexus of Theory, Experience, and Personal Preference, Technical Memorandum 006-2.

About the Author

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