Entrance Velocity: Its Importance to Well Design

Introduction

Among the many important parameters that figure into the design and operation of water wells, perhaps none engenders more misunderstanding than does the concept of maximum entrance velocity through water well screen. A commonly accepted design concept, proffered some 60 years ago as a general guideline for well design, is that water wells should be constructed with sufficient open area within the well screen so that during pumping the calculated entrance velocity will not exceed 0.1 feet per second (ft/second). Over the years, this concept has been the subject of model simulations and desktop studies which have shown it to be an ultra-conservative design parameter. While it is readily acknowledged that entrance velocity is an integral component of well design, model studies clearly indicate that the range of acceptable entrance is actually considerably higher than 0.1 ft/second, as will be described in this memorandum. For the well designer, this has important relevance when selecting the type and amount of well screen for a new well.

This memorandum is intended as a primer on entrance velocity for water wells. As such, important considerations are introduced and briefly explained. Well designers, particularly those new to water well design, are encouraged to investigate the various references presented herein for more detailed explanations of this subject. Other related and pertinent technical memoranda on well design have been prepared by Roscoe Moss Company and are available upon request.

Well Screen Open Area

Several types of well screens are available for construction of high-capacity water wells. Among these, the three most commonly installed in production wells for municipal, industrial, and agricultural use are: 1) louvered screens; 2) wire-wrapped screens; and 3) mill-slotted screens. Each of these options offers a range of open area per linear foot, as determined by the number of openings (i.e., slots) per linear foot and their dimensions (i.e., length and width). General information on open area for these screens is presented below.

Table 1 - Percent of Open Area*

Screen Type	Open Area (%)
Standard Louver	1.0
Ful Flo Louver	3.4
Super Flo Louver	10.1
Continuous Wire-Wrapped	34.0
Mill-slotted	0.74

Modified from Williams, D.E., 1981, The Aquifer-Model – Initial Test Results. The Roscoe Moss Co.

When designers strive to achieve a maximum entrance velocity of 0.1 ft/second, presumably they do so with several objectives in mind. One of these is that minimizing entrance velocity will maximize well efficiency. Obviously, well efficiency is an important design consideration; however, its relationship to extremely low (i.e., 0.1 ft/second) entrance velocity has been shown to be questionable, as described below.

Aquifer Model Testing

The simulated operation of the above-listed well screens (and several others) was investigated in aquifer model tests conducted by Dr. Dennis Williams, research professor, University of Southern California. Detailed descriptions of the aquifer model and the testing procedures are presented in a report entitled, "The Well-Aquifer Model – Initial Test Results" (1981). The purpose of aquifer model studies, as described by Dr. Williams, was "to investigate the interrelationships between well screens, gravel packs, and aquifers……" One of the specific objectives was to "determine the physical hydraulic relationships between screen entrance velocity, sand transportation and gravel pack design. In conjunction with this, test the validity of the 'opinion' by E. W. Bennison (1947) that entrance velocity must be between 0.1 and 0.25 ft/second.

The wedge-shaped physical model designed by Dr. Williams represented a typical section of an aquifer that received pure radial flow into a well. During its operation, the model simulated true field conditions by measuring flow through actual aquifer material, filter pack and the various types of well screen listed in Table 1. Among the many results of the model tests, the following was concluded with regard to entrance velocity:

> *"Above a minimum percentage of screen open area (3 – 5%), and entrance velocities less than 2.5 ft/second, well efficiency approaches a maximum and no significant increase in efficiency is achieved with an increase in percentage of open area."*

AWWA Standard for Water Wells

The American Water Works Association (AWWA) publishes its Standard for Water Wells (A-100-97) which specifically addresses the design and construction issues of water wells. A revised version of the document is in press and is due for publication in the 4th quarter of 2007. The Forward of the revised Standard presents the following statement with regard to entrance velocity:

> *"Many designers have, for various technical reasons, limited well-screen entrance velocities to not exceed 0.1 ft/second (0.03 m/second). Others have used and demonstrated successful well designs and installations with velocities substantially exceeding 0.1 feet/second, and the previous edition of this standard proposed an upper limit entrance velocity of 1.5 ft/second (0.46 m/second).*
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> *Based on a significant body of ongoing research within the ground water industry, the Committee recognizes as part of this current standard that there is no singular, uniquely defined criterion for permissible velocity through the screen slot openings that is solely suitable for designing a well without consideration of the aquifer characteristics and the manner of construction".*

The Standard's reference to total aperture area is presented as follows:

> "*The total aperture area of most commercial well screens is normally sufficient to achieve satisfactory well performance and efficiency. In general, well capacity does not directly correspond to variations in aperture area among manufacturers and methods of screen construction."*

DISCUSSION

The above-referenced aquifer model tests yielded empirical results that showed well efficiency is not enhanced if the entrance velocity is less than 0.1 ft/second. In fact, the model testing results demonstrated no appreciable gain in well efficiency if the entrance velocity is less than 2 to 4 ft/second. These findings are pertinent and significant to the practice of water well design, as well explained in the design scenarios described in AWWA-100-06 (in press).

In Appendix L-3, the new AWWA Well Standard presents two examples wherein the lengths of well screen are calculated for entrance velocities of 0.1 and 1.5 ft/second. The pertinent design parameters assumed were pumping rate, outside diameter of well screen, percentage of open area, unit capacity of screen face, and entrance velocity. The results show that the length of well screen is 15 times greater if one designs for an entrance velocity of 0.1 ft/second. This has serious implications for construction cost considering that no benefit in well efficiency would be realized.

Most water professionals would accept that AWWA sets forth reliable guidance documents and standards to its membership for the design and operation of water supply infrastructure. This includes well design. By recommending 1.5 ft/second as its maximum entrance velocity for water wells, AWWA presents clear guidance that well designers can use with confidence.

REFERENCES

American Water Works Association, 1997, Water Well Standard, A-100-97.

Handbook of Ground Water Development, 1990, Roscoe Moss Company, John Wiley and Sons, New York, NY

Ground Water – Its Development, Uses and Conservation, First Edition -1947, E.W. Bennison, Edward E. Johnson, Inc.

Williams, D.E., 1981, The Aquifer-Model – Initial Test Results. The Roscoe Moss Co.

___________, 1985, “Modern Techniques in Well Design”, Journal AWWA. Vol. 77, No. 9.

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