Year 2000 Proposed Additions to the High Plains Aquifer Water-Level Observation Network

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Summary

The Kansas Geological Survey (KGS) and the Division of Water Resources (DWR) maintain an observation network in Kansas to monitor variations in aquifer water level, mostly in the High Plains aquifer. The observation network in the High Plains aquifer is intended to have a maximum standard error of 10 ft calculated as kriging standard deviation.

We recommend the addition of 19 new observation wells to the High Plains aquifer network to compensate for past inadequacies of sampling that have resulted in areas with more than 10 ft of standard error. In addition, it is important that monitoring of three existing observation wells be resumed.

Two additional wells would be valuable to determine if abnormal measurements are the result of unusual but real fluctuations in water level or the result of poor mechanical conditions in observation wells.

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INTRODUCTION

The Kansas Geological Survey (KGS) and the Division of Water Resources (DWR) measure observation wells to monitor annual changes in water level in aquifers in Kansas. Most of the observation wells tap the High Plains aquifer and are arranged in a fairly systematic pattern or "network" that is employed to characterize the water level within the aquifer.

In theory, the best arrangement of wells in any two-dimensional observation network is a regular pattern with wells located at the centers of uniform hexagons (Olea, 1984). Because the present observation network was not originally constructed following a hexagonal pattern and the practical limitations of selecting observation wells from existing water wells, the Kansas High Plains aquifer observation network does not conform to an ideal regular hexagonal pattern. However, over the past two decades there has been systematic progress in modifying the network to approximate such an ideal sampling pattern.

This study is a review of proposed modifications to the network to further enhance the reliability in estimates of water levels at locations away from observation wells. The ultimate objective is to accurately monitor depletion and recharge in the aquifer.

THE OBSERVATION NETWORK IN THE YEAR 2000

There were 1240 wells at different sites scheduled to be measured during the January 2000 data acquisition season. Of these, 1176 were successfully measured (Olea and Davis, 2000).

KRIGING STANDARD DEVIATION FOR THE NETWORK

The kriging standard deviation is the geostatistical measure of reliability in spatial estimation (Olea, 1999c, Chapter 10). The larger the kriging standard deviation, the less reliable the associated estimate.

In 1997, the KGS assumed responsibility for measuring observation wells previously measured by the U.S. Geological Survey. It was agreed that a

standard error of 10 ft in the High Plains aquifer was a desirable and achievable level of reliability for the estimation of water table elevations (Olea, 1997a).

Selection of new wells to increase reliability of a network is fairly straightforward. It has been theoretically determined and confirmed in practice that, given the specific semivariogram model for the residuals of water-level elevation in the High Plains aquifer of Kansas (Gaussian with a nugget of 70 sq. ft, sill of 7910 sq. ft and range of 63,636 m), it is sufficient to have one well per hexagon of 4.5 km radius, arranged in a regular hexagonal pattern. This will result in a maximum kriging standard deviation of less than 10 ft. Figure 1 shows the appropriate hexagonal network drawn as the same scale as Plate 1. The pattern is usually robust enough to allow deviations of up to 2 miles from the proposed ideal site, depending on the locations of wells in the neighborhood.

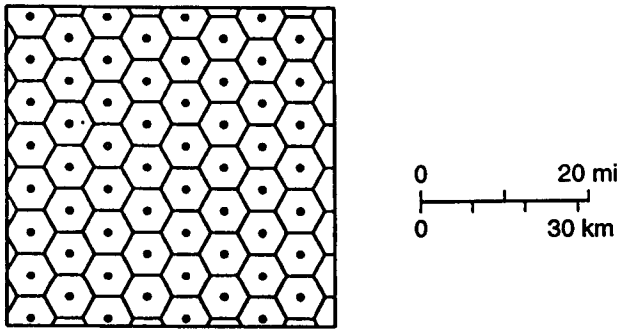

Figure 1—Regular hexagonal network of observation wells required to reduce the maximum standard error of water level measurements in the High Plain aquifer to 10 ft or less

REVIEW OF PROPOSED NETWORK MODIFICATIONS

Each year, based on kriging standard deviation maps, additional observation wells have been proposed for the network (Olea, 1997a; Olea, 1997b, Olea, 1998, Olea and Davis, 1999b). This year, nine new provisional observation wells were added to the network to fill in "holes" where the standard error exceeded 10 ft (Olea and Davis, 2000). These wells were located based on recommendations from last year (Olea and Davis, 1999b). In addition, two wells were added to check wells that had aberrant annual fluctuations.

The provisional wells added in January 2000 were helpful but insufficient to completely fill the network. Table 2 lists 19 wells that are needed to reduce the standard error to 10 ft or less except at the aquifer boundaries. With one exception, all locations are the same as those recommended last year when they

were listed in Table 3 of Open-file report 99-15 (Olea and Davis, 1999b). The exception is site 4, because a provisional observation well added this year was not close enough to the centroid (2.6 mi distant) to eliminate all of the area that had a standard error higher than 10 ft. The new centroid is a modification that considers the effect of the provisional observation well.

Table 1—Centroids proposed for locations of new wells to keep kriging standard deviations below 10 ft inside the High Plains aquifer. Numerical identification labels are the same as those in Plate 3 of Open-file Report No. 99-15 (Olea and Davis, 1999b)

		UTM coordinates			
Count	ID	Easting, m	Northing, m	Section	County
1.	4'	252000	4385000	5S 41W 35	Cheyenne
2.	5	366500.	4400000.	4S 29W 3	Decatur
3.	6	362000.	4391500.	4S 29W 32	
4.	13	352092.75	4180125.80	26S 31W 26	
5.	18	293505.49	4147498.97	30S 37W 11	Grant
6.	71	294000.	4170000.	27S 37W 35	
7.	72	298000.	4161000.	28S 36W 32	
8.	21	379130.00	4165221.08	28S 28W 10	Gray
9.	76	268000.	4137000.	31S 40W 13	Morton
10.	77	269000.	4129000.	32S 39W 7	
11.	29	310500.	4397000.	4S 35W 14	Rawlins
12.	61	310000.	4385500.	5S 35W 23	
13.	54	576500.	4207000.	23S 7W 31	Reno
14.	56	598000.	4210000.	23S 5W 21	
15.	33	343000.	4138303.33	31S 32W 2	Seward
16.	75	264000.	4157000.	29S 40W 14	Stanton
17.	57	283000.	4138000.	31S 38W 9	Stevens
18.	73	296000.	4136000.	31S 37W 14	
19.	78	312500.	4111000.	33S 35W 34	

During the year 2000 annual measuring season, 64 wells were not measured. Three of these wells, listed in Table 2, are necessary if the kriging standard deviation is to be limited to 10 ft. The Harvey County well (USGS ID 375811097373001) has not been measured for the past two years. The other two wells were missed just this year (USGS ID 392210100384601 and 392901101093401).

Finally, the wells listed in Table 3 are necessary to check observation wells that exhibit anomalous water-level fluctuations.

Table 2—Existing observation wells not measured in year 2000 but required to keep the kriging standard deviation below 10 ft inside the High Plains aquifer. Numerical identification labels are the same as those in Open-file Report No. 99-11 (Olea and Davis, 1999a)

		UTM coordinates			
Count	ID	Easting, m	Northing, m	Section	County
1.	615	620579.8	4203134.5	24S 3W 14BBB	Harvey
2.	1163	358352.8	4358850.0	8S 30W 11CBC	Sheridan
3.	1223	314222.9	4372606.0	6S 34W 31CDB	Thomas

Table 3—Centroids of locations of new wells needed to confirm measurements in observation wells that exhibit erratic year-to-year behavior. Numerical identification labels are the same as those in Plate 3 of Open-file Report No. 99-15 (Olea and Davis, 1999b)

		UTM coordinates			
Count	ID	Easting, m	Northing, m	Section	County
1.	94	324000.	4214000.	23S 34W 13	Decatur
2.	91	303000.	4121000.	32S 36W 34	Stevens

A WORD ABOUT THE PLATE

Plate 1 is a posting map showing the outline of the High Plains aquifer in Kansas. Each well symbol represents the center of an imaginary circle 4 miles in diameter. Where a new provisional observation well is required, the well should be located within 2 miles, preferably as close to the center as possible. If possible, wells drilled within the last ten years should be chosen because new wells are in better condition, have better downhole access, and have a longer expected life.

Three different symbols are used on the map corresponding to the sites in Tables 1-3; a red plus (+) indicates a location where a new observation well is needed; a blue cross (x) denotes the location of an existing observation well that was not measured in 2000 but which is required in future years; and a green open circle (o) indicates a location where a well is needed to confirm measurements in observation wells with erratic year-to-year behavior.

YEAR 2000 ACCURACY IMPROVEMENT

If the nine provisional observation wells had not been added to the network this year, significant estimation errors would have occurred at the nine localities. Figure 2 shows the estimation errors in the water-table elevation map at the sites of the provisional observation wells when these wells are removed from the data set.

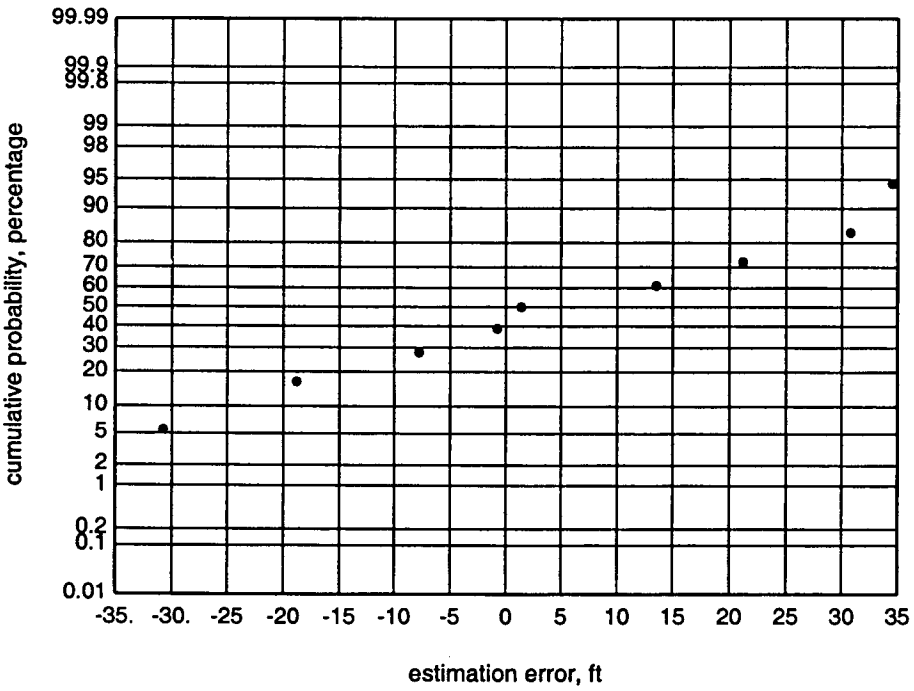

Figure 2—Estimation error in water-table elevation at nine proposed observation wells, if the wells had not been measured this year. Positive values denote overestimation in the elevation. Plot is cumulative probability of occurrence versus error.

Although this is a very small sample, it is worthwhile to note that the average absolute discrepancy in water level elevation is 18 ft and the maximum discrepancy is 35 ft. These values are a good estimate of the errors in water-table elevation that are to be expected at those sites listed in Tables 1 and 2 as long as these sites remain unsampled.

CONCLUSIONS AND RECOMMENDATIONS

From the analysis of the year 2000 reliability map for water table elevation in the High Plains aquifer and a review of previous recommendations, we conclude that:

1. A total of 19 new observation wells must be added to the High Plains network to achieve a maximum kriging standard deviation of 10 ft or less throughout the central portions of the major High Plains aquifer. The number of proposed new wells is 2% fewer than the number of new wells recommended last year, indicating a systematic reduction in the gaps in the network.

2. It is important to measure three existing observation wells that were not measured in year 2000 in order to limit the kriging standard deviation to less than 10 ft except near the aquifer boundaries.

3. Two new observation wells near wells with unusual annual fluctuations are needed to determine if their behavior is real or the result of poor measurements. The number of wells proposed for this purpose is half the number that were proposed last year.

4. Without the addition of nine preliminary observation wells in January 2000, the average absolute discrepancy with reality at those sites would have been 18 ft

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PROPOSED ADDITIONS TO HIGH PLAINS AQUIFER NETWORK, JANUARY 2000

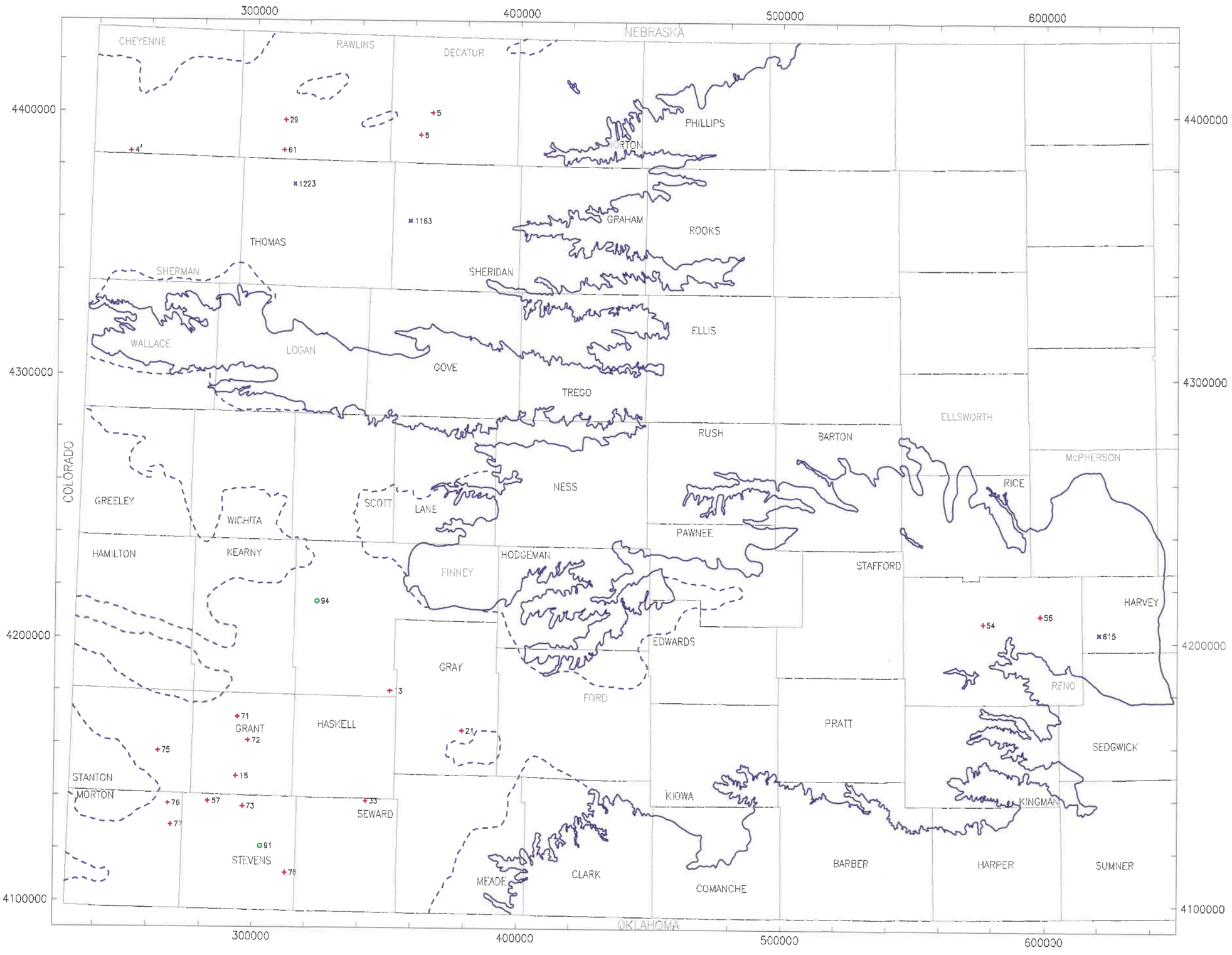

PLATE 1

Kansas Geological Survey
OFR 2000-17
Olea & Davis