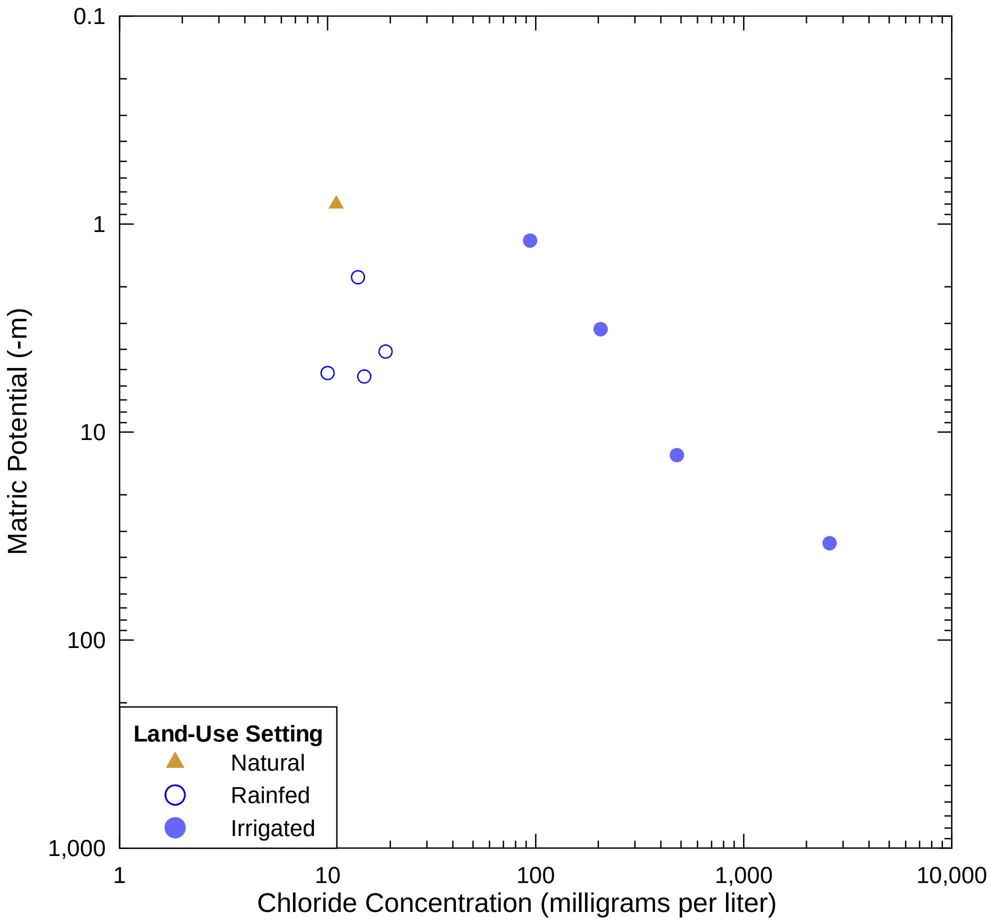

Figure 4.4.6 **Relationship between matric potential and chloride concentration for boreholes in the unsaturated zone studies in the Seymour Aquifer.**

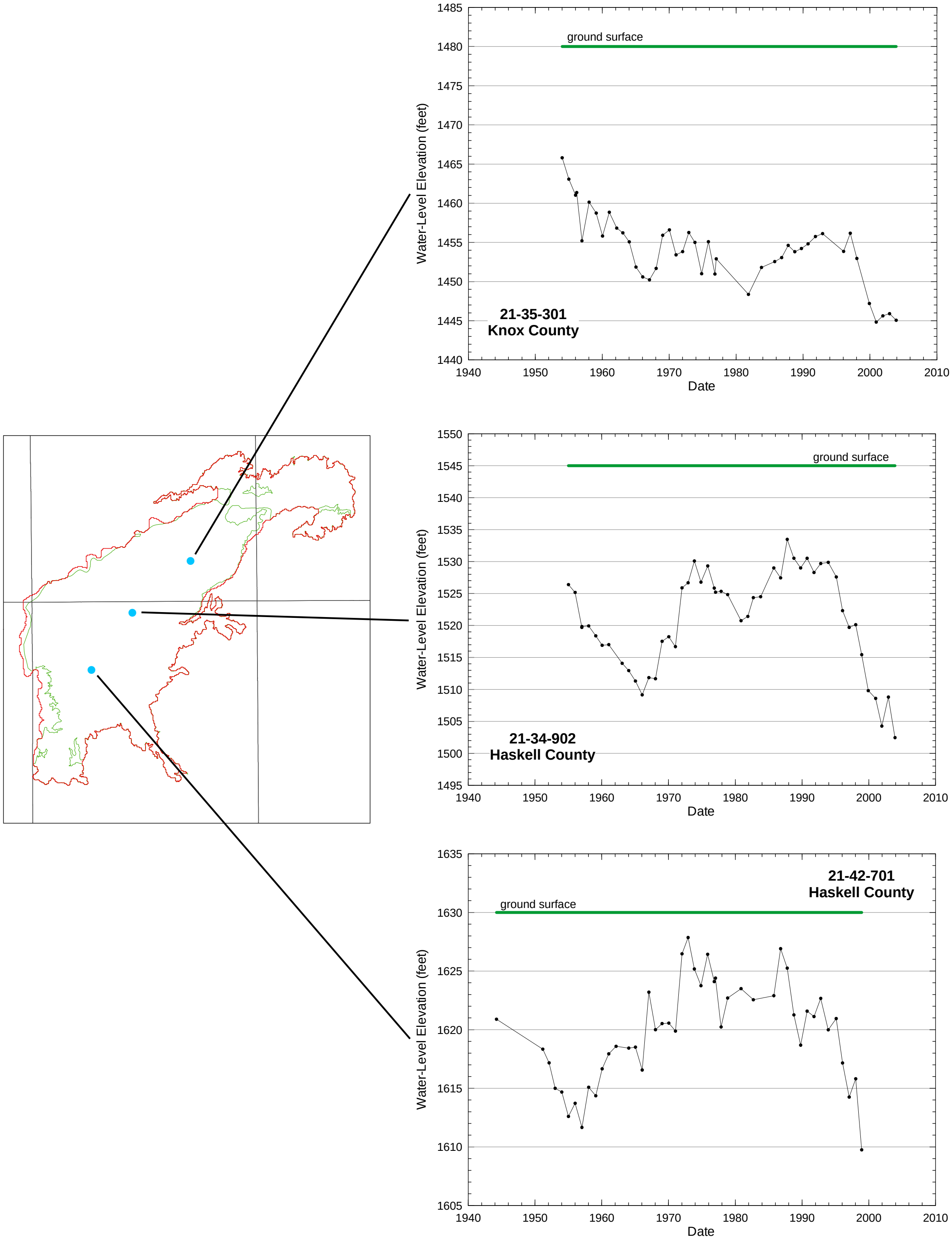

Figure 4.4.7 **Long-term water-level data used to estimate recharge rates for the Seymour Aquifer using the water-table fluctuation method.**

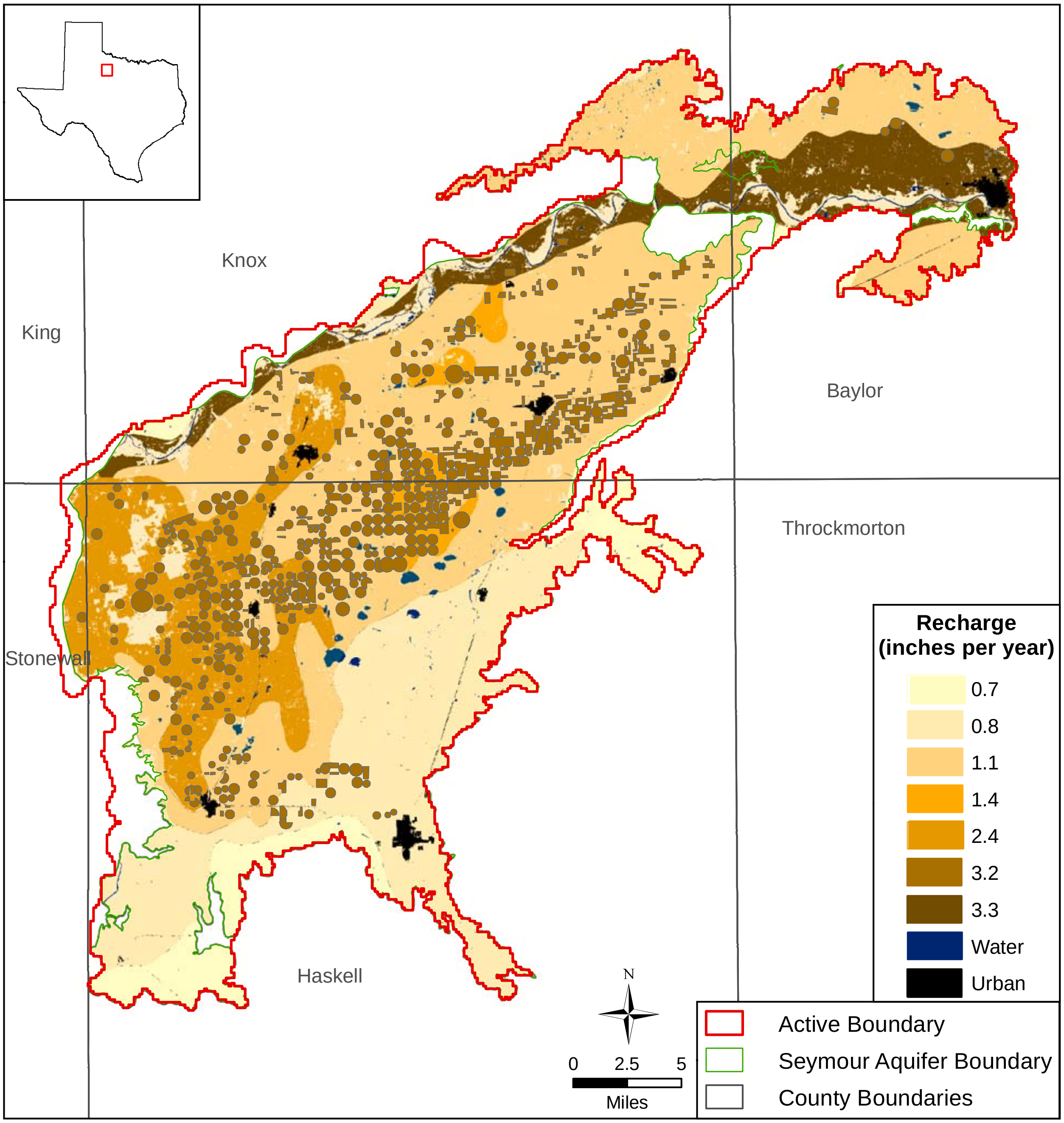

Figure 4.4.8 **Estimated spatial distribution of modern recharge for the Seymour Aquifer.**

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4.5 Rivers, Streams, Springs, and Lakes

Interaction between groundwater and surface water occurs at the location of rivers, streams, springs, and lakes. Rivers and streams can either lose water to the underlying aquifer, resulting in aquifer recharge, or gain water from the underlying aquifer, resulting in aquifer discharge. Discharge from an aquifer also occurs where the water table intersects the ground surface at springs or seeps. Lakes can provide a potential site of focused recharge.

4.5.1 Rivers and Streams

Base flow in a river or stream is the contribution of groundwater to gaining reaches of a stream. After runoff from storm events has drained away, the natural surface-water flow that continues is predominately base flow from groundwater. Streams can have an intermittent base flow with flow during wet periods and low or no flow during dry periods. Larger streams and rivers might have a perennial base flow. Direct exchange between surface water and groundwater is limited to the outcrop.

One major river, two large creeks, and four small creeks intersect the study area (Figure 4.5.1). The locations of the major river and two large creeks were obtained from the United States Environmental Protection Agency reach file 1 for the conterminous United States (Alexander and others, 1999), clipped to the active model area, and the locations for the four small creeks were digitized from a scanned image of a United States Geological Survey topographic map obtained from the Texas Natural Resources Information System website (TWDB, 2005). The names for these four small creeks were taken from R.W. Harden and Associates (1978). Because the locations of the four small creeks were digitized from a figure, they are less certain than the locations of the major river and two large creeks.

Also shown on Figure 4.5.1 is the location of the one stream gage, where stream-flow data are collected, available for the river in the study area. This gage is located on the Brazos River in Baylor County. Figure 4.5.2 shows a hydrograph of the yearly average stream flow at this gage over the period of record from 1924 through 2008. This yearly average stream flow was calculated from daily stream flow data obtained from the United States Geological Survey website of surface water data for the nation (United States Geological Survey, 2009b). The yearly average has ranged from a low of 48 cubic feet per second in 1952 to a high of 1,786 cubic feet per second in 1941. During the transient model calibration period of 1980 through 1997, the yearly average ranged from a low of 92 cubic feet per second in 1984 to a high of 632 cubic feet per second in 1992. A pattern of relatively low stream flow for one or two years followed by significantly higher flow for the next two or three years occurs three times during the transient model calibration period of 1980 through 1997. However, stream flow was continually low from 1993 through 1997. Figure 4.5.3 shows the daily and monthly average stream flow at the gage during the transient model calibration period. The grid lines on the monthly average figure indicate the month of January in each year. A comparison of this grid line to the data does not show a consistent seasonal trend in the monthly average stream flow. Although the lowest stream flows occurred in the summer months of 1983, 1984, and 1996, several of the highest streams flows also occurred in summer months (i.e., 1982, 1990, 1991, and 1992).

Stream interaction with underlying aquifers can be quantified through stream gain/loss studies that determine the rate of water exchange between a stream and the adjacent aquifers. A low-flow gain/loss study was conducted in February 1970 on the Brazos River from the Knox-Baylor county line to the bridge over the river at the city of Seymour in Baylor County (Preston, 1978). Gains/losses in stream flow were measured at five sites along this portion of the river. The approximate locations of measurements sites 2, 3, 4, and 5 are shown in Figure 4.5.1. The location of measurement site 1 is not shown on this figure because it was not given in Preston (1978). Table 4.5.1 summarizes the stream flow measured at each site, the net gain, and the yearly discharge from the Seymour Aquifer represented by the gain. The study showed that this portion of the Brazos River is gaining, with the net gain ranging from 0.1 to 2.6 cubic feet per second (Table 4.5.1). The gains observed along the river indicate discharge from the Seymour Aquifer to the river. Preston (1978) calculated the magnitude of this discharge to range from 72.4 to 1,882.5 acre-feet per year (Table 4.5.1). Note that along this portion of the Brazos River, the Seymour Aquifer includes groundwater in the Seymour Formation as well as groundwater in the recent alluvium sediments located adjacent to the river. The majority of the groundwater discharging to the river comes from the Seymour Formation and travels through the recent alluvial deposits to the river (Preston, 1978). The Slade and others (2002) report on gains from and losses to major and minor aquifers in Texas does not include stream gain/loss study data for the Seymour Aquifer.

4.5.2 Springs

In unconfined aquifers, springs are locations where the water table intersects the ground surface. Springs typically occur in topographically low areas in river valleys or in areas of the outcrop where hydrogeologic conditions preferentially reject recharge. Four sources were used to find spring data for the Seymour Aquifer; the TWDB website (TWDB, 2008c), a database of Texas springs compiled by the United States Geological Survey and reported in Heitmuller and Reece (2003), a report on the springs of Texas by Brune (2002), and the R.W. Harden and Associates (1978) report on the availability and quality of groundwater in the Seymour Aquifer in Haskell and Knox counties. Note that all of the springs identified in the report in the occurrence and quality of groundwater in Baylor County by Preston (1978) are included in TWDB (2008c). All of the springs found in Heitmuller and Reece (2003) were also found on the TWDB website (TWDB, 2008c).

The TWDB website and Heitmuller and Reece (2003) provide coordinates for springs but Brune (2002) does not. An exercise was conducted to try to determine the locations of the springs given in Brune (2002) by first looking at the discharge rates from the springs. If the rate was low, those springs were considered to be unimportant and not evaluated further. For springs with high discharge rates, an attempt was made to match the spring with a spring found in TWDB (2008c). For three springs this was easily done because the name of the spring in Brune (2002) matched the name of the spring in TWDB (2008c) and/or Heitmuller and Reece (2003). Several other springs were matched to a spring in TWDB (2008c) based on the description of the spring location given in Brune (2002) and/or based on the flow measurements given in Brune (2002) and TWDB (2008c). The certainty of this match is high for some springs but low for others. Six of the springs in Brune (2002) had a high discharge rate but could not be matched to a spring in TWDB (2008c). For those springs, an approximate location was estimated based on the location description given in Brune (2002).

Figure 4.5.4 shows the locations of springs flowing from the Seymour Aquifer obtained from the TWDB website (TWDB, 2008c), Heitmuller and Reece (2003), and Brune (2002). The springs are predominately located along the Brazos River in Baylor County and along the western edge of the Seymour Aquifer in Knox and Haskell counties. Table 4.5.2 provides a summary of flow from Seymour Aquifer springs. A flow rate is not available for several of the springs and only one flow rate is available for many of the springs. For the springs with more than one measurement, spring discharge has generally declined over time. Brune (2002) attributes this decline primarily to pumping of the Seymour Aquifer for irrigation purposes. More than two discharge measurements are available for only three of the springs. A plot of discharge for those three springs is provided in Figure 4.5.5.

R.W. Harden and Associates (1978) provide a figure showing areas of natural discharge from the Seymour Aquifer. That figure, reproduced as Figure 4.5.6, shows the locations of springs and zones of springs and seeps in creeks. A comparison of Figures 4.5.4 and 4.5.6 shows that the location for some, but not all, of the springs on the R.W. Harden and Associates (1978) figure match locations for springs found in TWDB (2008c). Volume II of the R.W. Harden and Associates (1978) report also contains a table with a record of wells, which includes springs. All of the springs in that table are included in TWDB (2008c). Coordinate and discharge data for springs shown on their figure but not included in their record of wells table are not provided by R.W. Harden and Associates (1978).

Brune (2002) reports that buffalo bones and Indian artifacts were found at several Seymour Aquifer springs in Baylor, Haskell, and Knox counties. He also found evidence of camp sites for buffalo hunters and Indians near several springs. Brune (2002) states that Rice Springs near the city of Haskell was flowing in 1867, 1875, and 1881 and that a spring in Baylor County fed a pool used for baptisms in the 1880s. This information indicates that that the Seymour Aquifer contained some water in the steady-state period prior to about 1880.

4.5.3 Lakes and Reservoirs

Figure 4.5.7 shows reservoirs located within the study area. None of these reservoirs lie on the Seymour Aquifer. Although it is difficult to see in Figure 4.5.7, a portion of Lake Davis falls within the active model area, but the boundary of the Seymour Aquifer does not include the lake. Figure 4.5.7 also shows the locations of several playas on the Seymour Aquifer. These playas contain water intermittently based on rainfall (McGuire, 2009). Most of the playas are located over the portion of the aquifer that is dry. The playas on the portion of the aquifer that contains water may be a source of focused recharge. However, their impact is expected to be insignificant.

Table 4.5.1 Summary of the February 1970 gain/loss study on the Brazos River in Baylor County (after Preston, 1978).

Measurement Site	Flow (cubic feet per second)	Net Gain (cubic feet per second)	Yearly Discharge Represented by Net Gain (acre-feet)
1	34.6	-	-
2	34.7	0.1	72.4
3	35.2	0.5	362.5
4	37.8	2.6	1,882.5
5	38.7	0.9	651.6

Table 4.5.2 Summary of springs flowing from the Seymour Aquifer in the study area.

Spring Number/ Name	Possible Spring in Brune (2002)	County	Elevation (feet)	Max Flow (gpm)	Max Flow (lps)	Date of Max	Min Flow (gpm)	Min Flow (lps)	Date of Min	Number of Measure-ments	Source
21-21-703	Soap Springs	Baylor	1388	30	**1.9**	10/1969	16	**1.0**	7/21/1979	3	TWDB (2008c), Brune (2002)
21-22-406	Dead Man Springs	Baylor	1280	10	**0.63**	10/1969	5.5	**0.35**	7/21/1979	2	TWDB (2008c), Brune (2002)
21-22-407		Baylor	1285	**15**	0.95	nr				1	TWDB (2008c)
21-22-408		Baylor	1285	**15**	0.95	nr				1	TWDB (2008c)
21-22-910		Baylor	1346	**2**	0.1	nr				1	TWDB (2008c), Heitmuller and Reece (2003)
21-29-317		Baylor	1300	**5**	0.3	nr				1	TWDB (2008c)
21-29-701		Baylor	1385							0	TWDB (2008c)
21-30-201		Baylor	1290	**10-15**	0.63-0.95	nr				1	TWDB (2008c)
21-30-214/ Buffalo Springs	Buffalo Springs	Baylor	1268	44	**2.8**	8/7/1925	12	**0.75**	1/22/1969	3	TWDB (2008c), Heitmuller and Reece (2003), Brune (2002)
21-30-262		Baylor	1267	**15**	0.95	nr				1	TWDB (2008c)
21-30-263		Baylor	1290	**15**	0.95	nr				1	TWDB (2008c)
21-30-383		Baylor	1303	**10**	0.63	nr				1	TWDB (2008c)
21-30-384		Baylor	1280	**5**	0.3	nr				1	TWDB (2008c)
21-30-603		Baylor	1332							0	TWDB (2008c)
21-39-604		Baylor	1260	**15**	0.95					1	TWDB (2008c)
21-30-393		Baylor		**67.32**	4.247	8/7/1925				1	TWDB (2008c), Heitmuller and Reece (2003)
Cottonwood Holes		Baylor		12	**0.75**	7/21/1979				1	Brune (2002)

Table 4.5.2, continued

Spring Number/ Name	Possible Spring in Brune (2002)	County	Elevation (feet)	Max Flow (gpm)	Max Flow (lps)	Date of Max	Min Flow (gpm)	Min Flow (lps)	Date of Min	Number of Measure-ments	Source
21-41-131	McGregor Springs	Haskell	1495	27	**1.7**	9/9/1979				1	TWDB (2008c), Heitmuller and Reece (2003), Brune (2002)
21-49-505	nr	Haskell	1650	**25**	1.6	3/20/1944	10	**0.61**	9/8/1979	2	TWDB (2008c), Heitmuller and Reece (2003), Brune (2002)
21-50-639		Haskell	1582							0	TWDB (2008c), Heitmuller and Reece (2003)
21-51-717/ Rice Spring	Rice Springs	Haskell	1560	55	**3.5**	9/7/1979	**dry**		8/6/1975	4	TWDB (2008c), Heitmuller and Reece (2003), Brune (2002)
Cook Springs		Haskell		41	**2.6**	9/9/1979				1	Brune (2002)
21-27-921	Redder Springs	Knox	1375	8.7	**0.55**	9/2/1979				1	TWDB (2008c), Heitmuller and Reece (2003), Brune (2002)
21-27-922		Knox	1365							0	TWDB (2008c), Heitmuller and Reece (2003)
21-28-601		Knox	1390	**1**	0.1	11/5/1975				1	TWDB (2008c), Heitmuller and Reece (2003)
21-28-602		Knox	1400							0	TWDB (2008c), Heitmuller and Reece (2003)
21-34-323	Mansfield Springs	Knox	1405	**100**	6.31	2/10/1957	**seeps**		9/1/1979	2	TWDB (2008c), Heitmuller and Reece (2003), Brune (2002)

Table 4.5.2, continued

Spring Number/ Name	Possible Spring in Brune (2002)	County	Elevation (feet)	Max Flow (gpm)	Max Flow (lps)	Date of Max	Min Flow (gpm)	Min Flow (lps)	Date of Min	Number of Measure-ments	Source
21-34-445/ Chalk Springs	Chalk springs	Knox	1445	**75**	4.73	3/1957	15	**0.95**	8/31/1979	3	TWDB (2008c), Heitmuller and Reece (2003), Brune (2002)
21-35-105		Knox	1405							0	TWDB (2008c), Heitmuller and Reece (2003)
21-35-106		Knox	1415							0	TWDB (2008c), Heitmuller and Reece (2003)
21-36-602		Knox	1412	**0.125**	0.008	11/6/1975				1	TWDB (2008c), Heitmuller and Reece (2003)
Bluff Springs		Knox		9.8	**0.62**	9/1/1979				1	Brune (2002)
Mockingbird Springs		Knox		21	**1.3**	9/3/1979				1	Brune (2002)
W Cross Springs		Knox		5.5	**0.35**	9/3/1979				1	Brune (2002)
Wild Horse Springs		Knox		81	**5.1**	9/3/1979				1	Brune (2002)

Note: Bold information reflects values and text given in the data source.
gpm = gallons per minute
lps = liters per second
TWDB = Texas Water Development Board

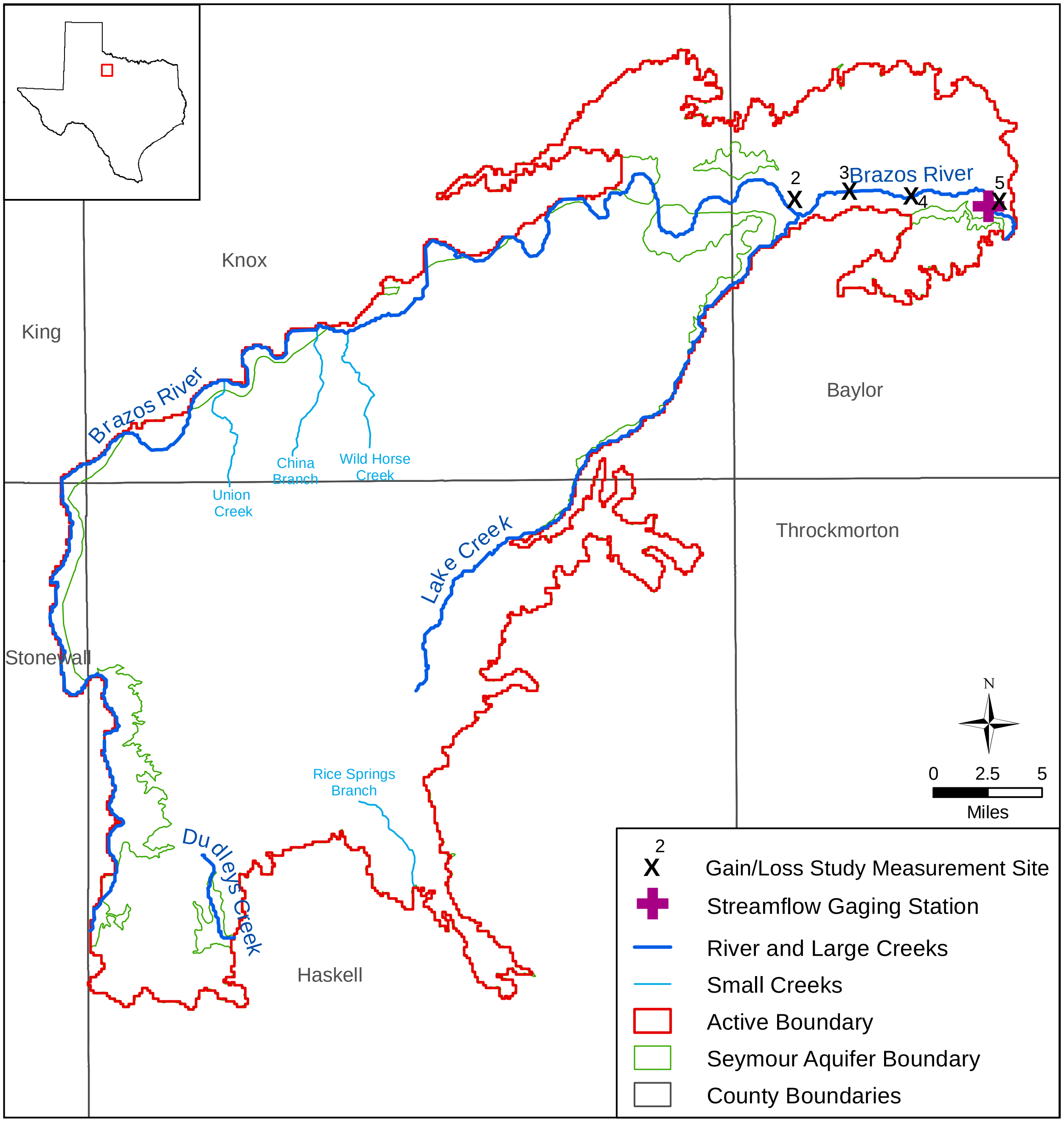


Figure 4.5.1 **Locations of major river, large creeks, and small creeks in the model area.**

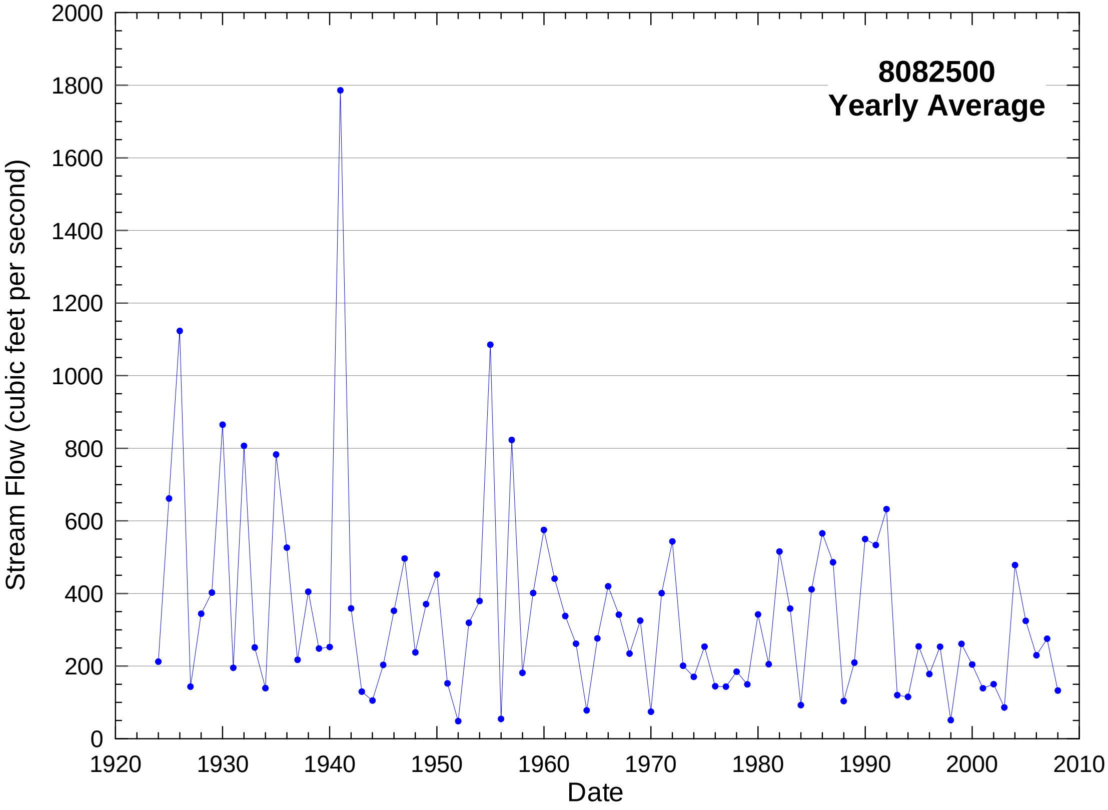


Figure 4.5.2 **Hydrograph of yearly average stream flow for the gage on the Brazos River in Baylor County.**

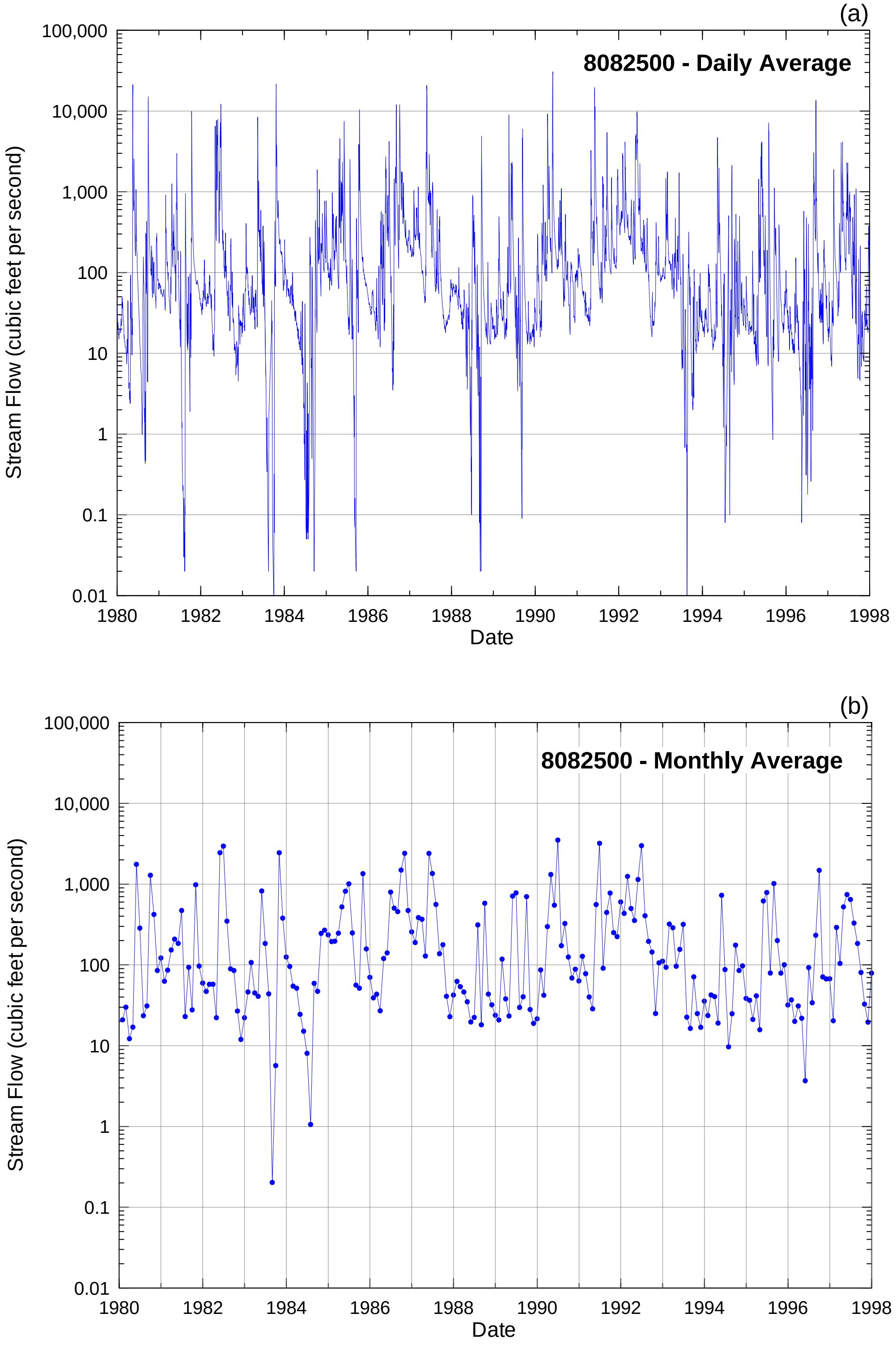


Figure 4.5.3 Hydrograph of (a) daily and (b) monthly average stream flow for the gage on the Brazos River in Baylor County during the calibration period (1980 to 1997).

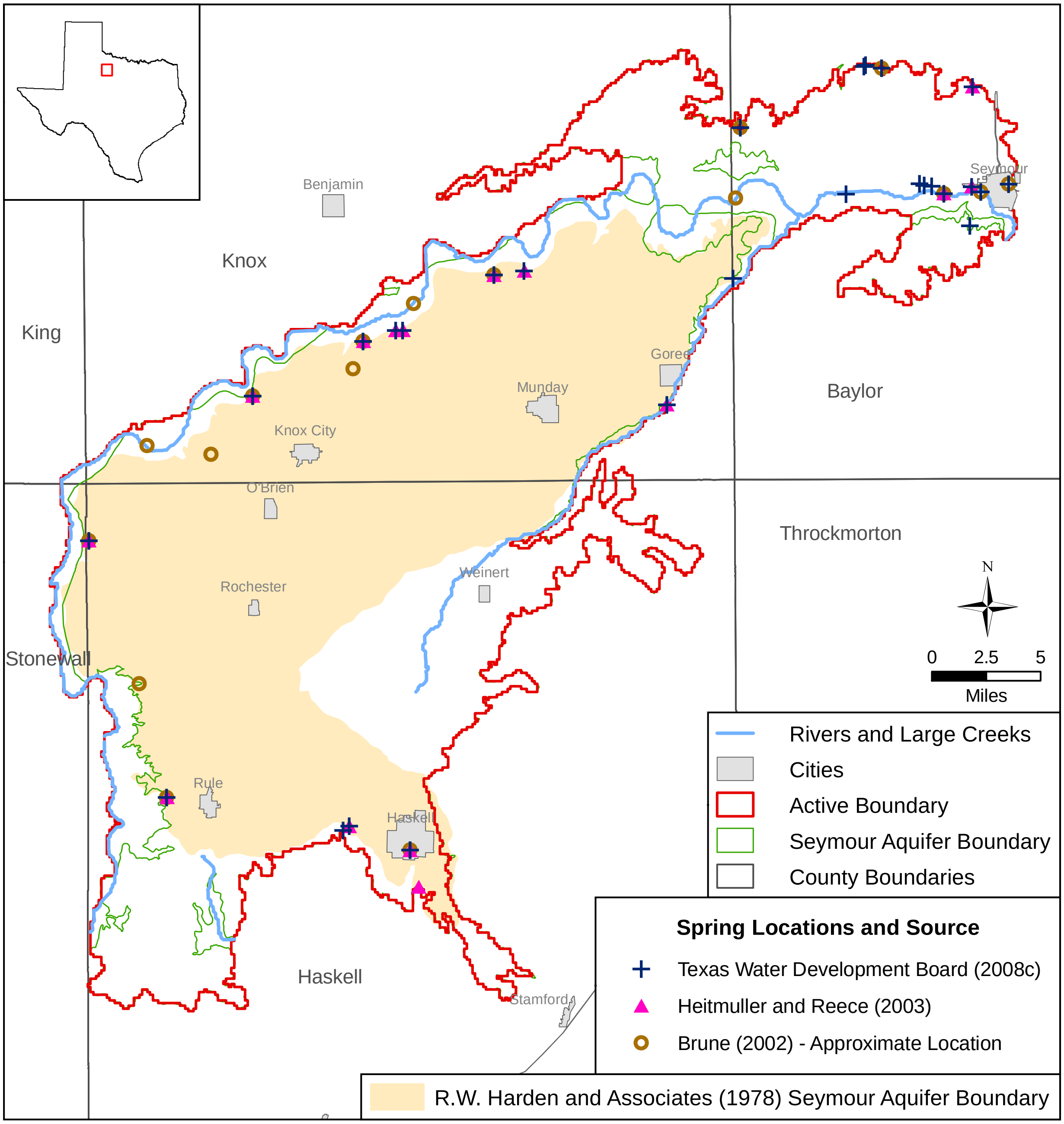


Figure 4.5.4 **Locations of springs flowing from the Seymour Aquifer in the study area.**

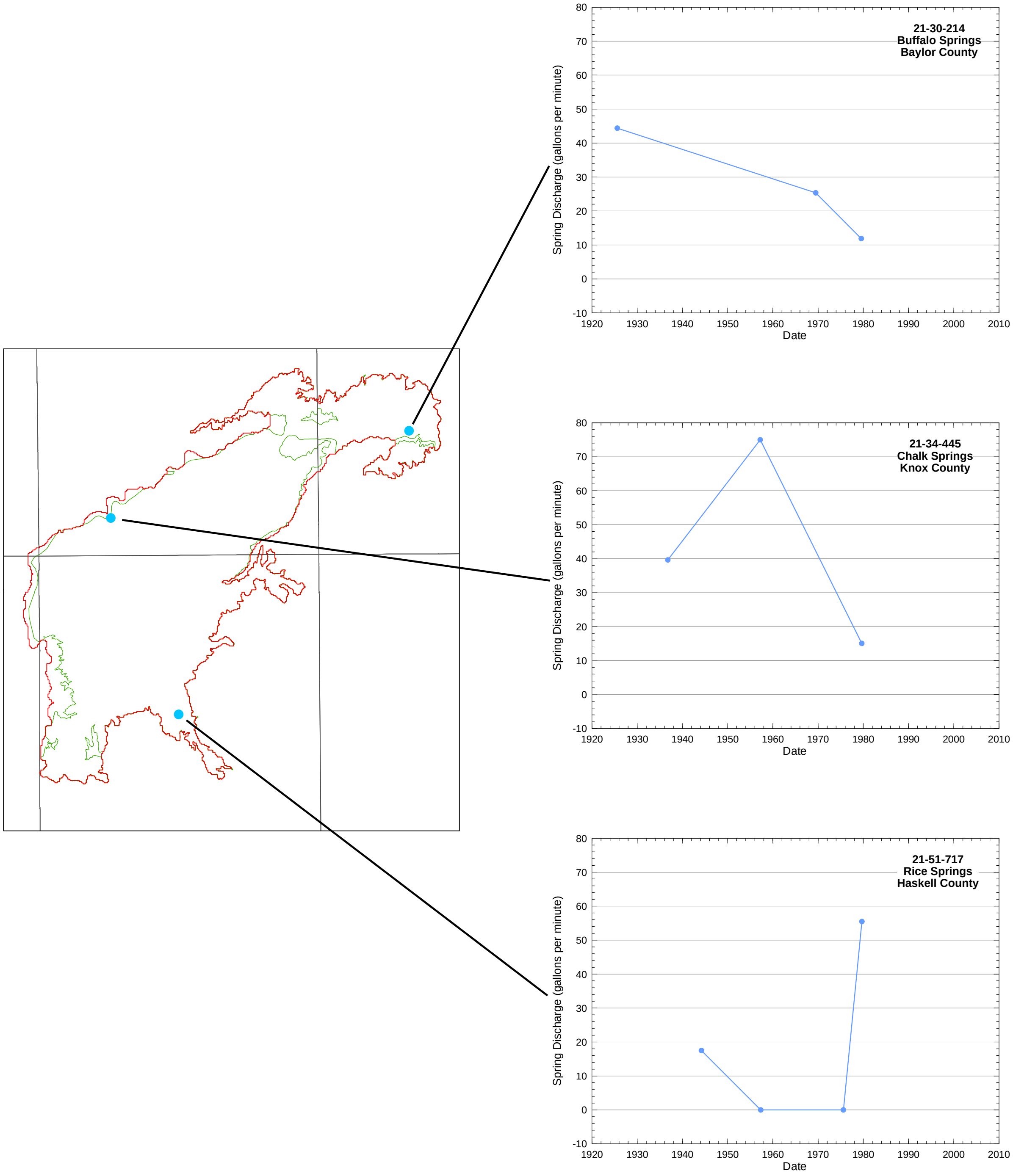


Figure 4.5.5 Hydrographs of discharge for selected springs flowing from the Seymour Aquifer.

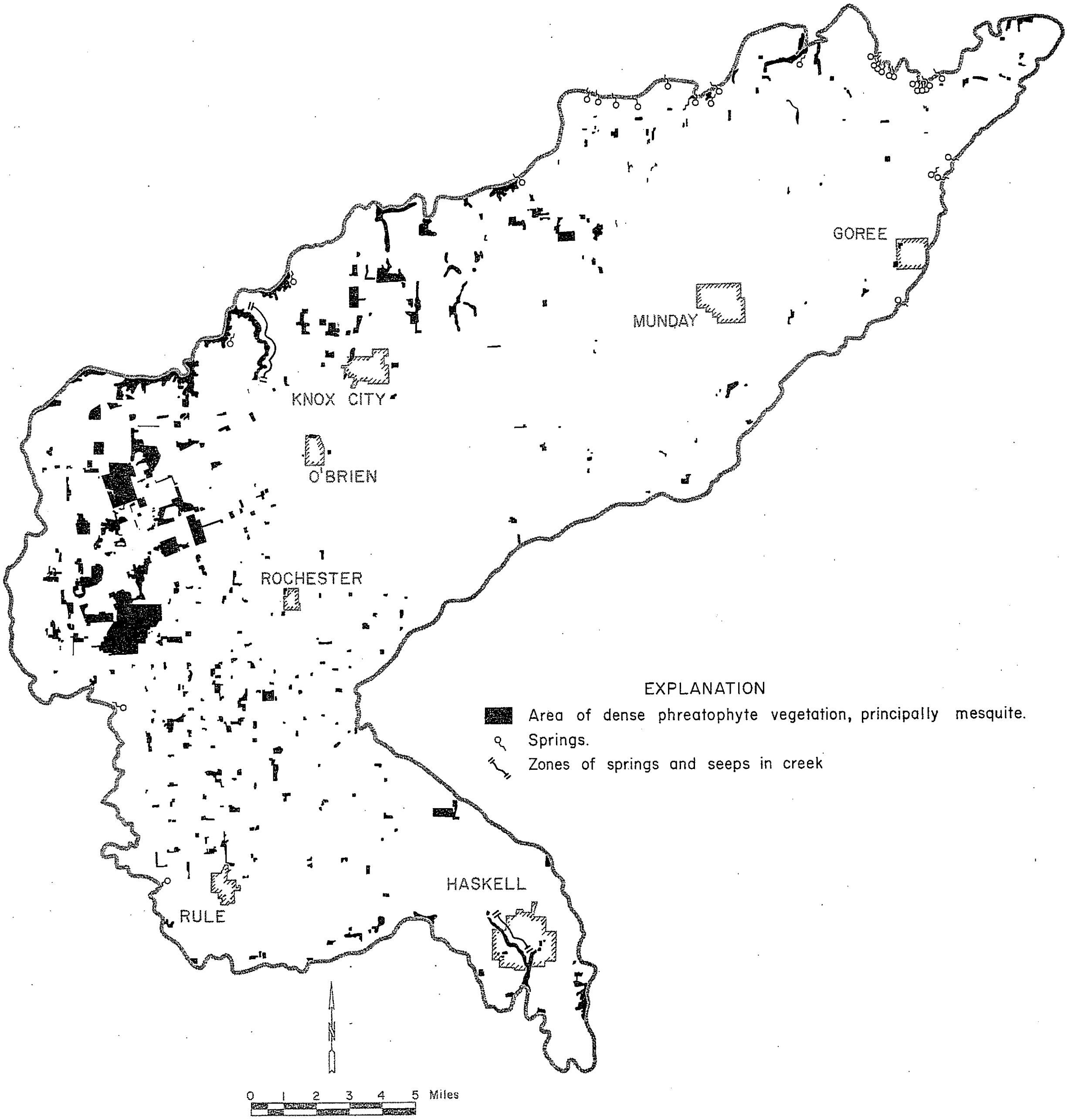


Figure 4.5.6 Locations of springs and zones of springs and seeps given in R.W. Harden and Associates (1978).

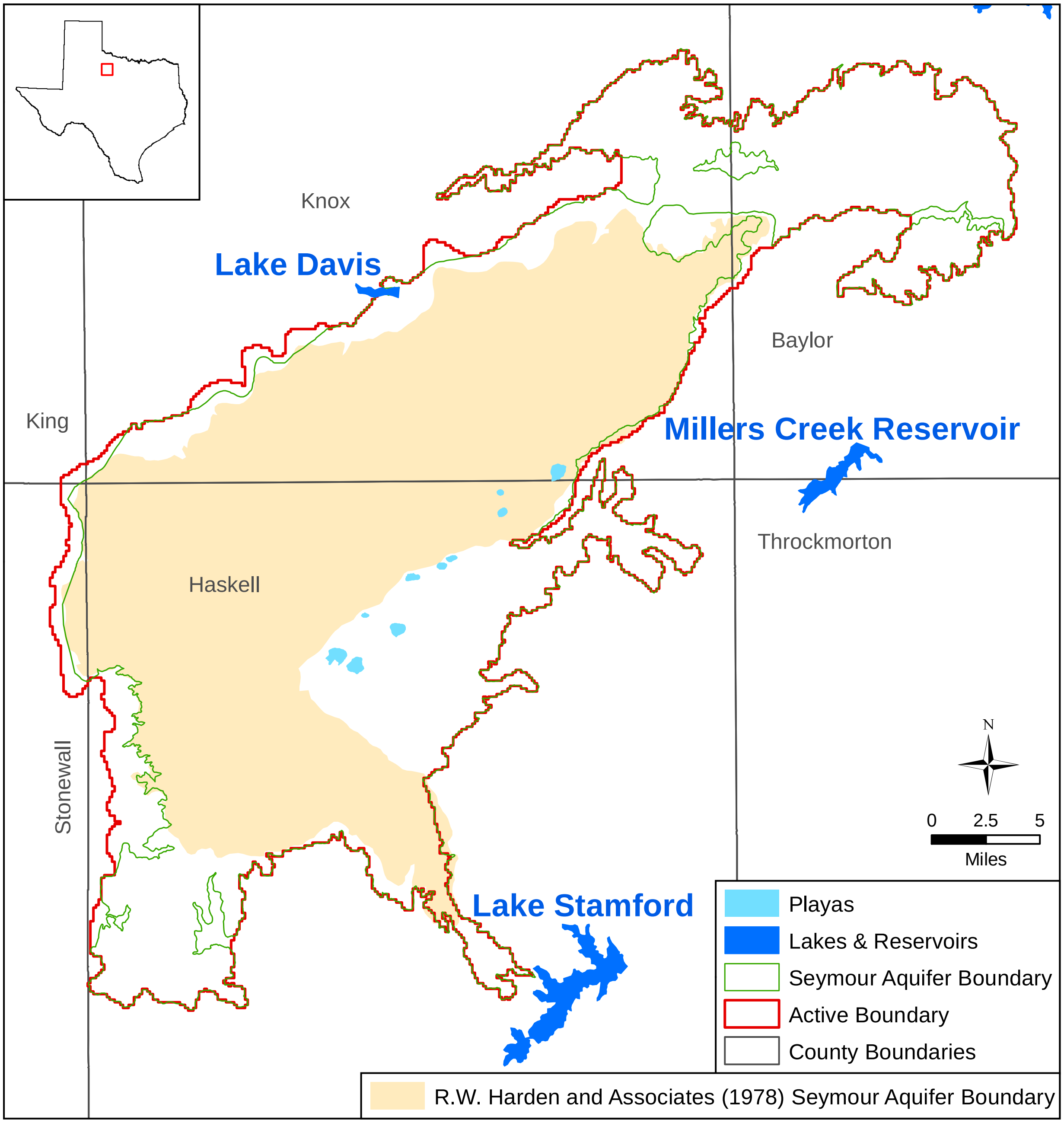


Figure 4.5.7 Locations of reservoirs and playas in the study area.

4.6 Hydraulic Properties

The Seymour Aquifer in Haskell, Knox, and Baylor counties includes the Seymour Formation and other Quaternary-age alluvium. The Seymour Formation generally consists of fluvial sheet deposits of clays, silts, sands, gravels and conglomerates, and some caliche and volcanic ash, that are isolated by incised river valleys. The Quaternary-age alluvium, which was deposited by the Brazos River, consists of silt, sand, and gravel derived primarily from the Seymour Formation. A fairly consistent deposit of sands and gravels is present near the base of the Seymour Formation over much of the model domain resulting in reasonably high permeabilities. The underlying Permian System, which includes the Clear Fork Group and a very small portion of the Wichita Group in the active model domain, consists of generally low-permeability rocks with poor water transmitting characteristics.

4.6.1 Data Sources

Development of hydraulic properties for the Seymour Aquifer considered transmissivity, hydraulic conductivity, specific capacity, and storage values reported in various TWDB reports, from the TWDB website (TWDB, 2008c), and from Texas Commission on Environmental Quality and Rolling Plains Groundwater Conservation District well records. Hydraulic properties for the Clear Fork Group were developed using specific capacity data from Texas Commission on Environmental Quality well records. The locations and sources of the hydraulic property data for the Seymour Aquifer are given in Figure 4.6.1.

4.6.2 Calculation of Hydraulic Conductivity from Specific Capacity

Because specific capacity is relatively easy to measure, requiring knowledge of only the pumping rate and drawdown, it is commonly reported in well records. However, hydraulic conductivity is a more useful parameter than specific capacity for regional groundwater modeling. The methodologies presented in Mace (2001) were used in an attempt to estimate hydraulic conductivity from specific capacity.

For the Seymour Aquifer, transmissivity and specific capacity were measured at 32 coincident locations (R.W. Harden and Associates, 1978; Myers, 1969). From these paired values, an attempt at an empirical correlation relating transmissivity to specific capacity was made as depicted in Figure 4.6.2. The low coefficient of determination of 0.3282 implies a very weak correlation between the two properties. In other words, only approximately 30 percent of the variability in transmissivity can be explained by specific capacity alone. For this reason, specific capacity measurements were not used to augment the hydraulic properties for the Seymour Aquifer. For each of the well tests reported by R.W. Harden and Associates (1978), the saturated thickness of the aquifer at the location was noted and used to calculate hydraulic conductivity from transmissivity.

No transmissivity measurements are available for the Clear Fork Group, so no empirical relationship could be developed to estimate transmissivity from the specific capacity measurements. Instead, the analytical methodology presented in Mace (2001) was used to estimate transmissivity for these units. Specifically, the analytical method of Theis and others (1963) was used. The empirical correction for well loss according to Equation 64 of Mace (2001) was applied to the drawdowns; however, the low conductivity of the Clear Fork Group sediments and the correspondingly low pumping rates resulted in negligible well losses (average of 1 percent) in most cases. Hydraulic conductivity was calculated from transmissivity using well screen length for these data. No transmissivity or specific capacity measurements were available for the Wichita Group.

4.6.3 Analysis of the Hydraulic Property Data

Figure 4.6.3 shows a histogram of the hydraulic conductivity data for the Seymour Aquifer. This figure indicates that the data are closer to being lognormally distributed than being normally distributed. Summary statistics of the hydraulic conductivity data for the Seymour Aquifer and Clear Fork Group are presented in Table 4.6.1. The similarity between the geometric mean and median for both formations indicates that the distribution of hydraulic conductivity is approximately lognormal. While the Clear Fork Group exhibits low mean hydraulic conductivity values, the actual value may be still lower than that presented. This is because wells in the Clear Fork Group are necessarily located in the highest conductivity portions of the formation and, therefore, biased high.

4.6.4 Variogram Analysis of Hydraulic Conductivity

The spatial distribution of hydraulic properties can be characterized by a variogram analysis. A variogram analysis quantifies gross spatial correlation and variability (for detailed background information on geostatistics, refer to Isaaks and Srivastava, 1989). Typical hydrogeologic properties show some spatial correlation indicated by lower variance for nearby measurements. As the distance between measurements increases, variance increases until it becomes constant. That constant value corresponds to the ensemble variance of the entire dataset. At the separation distance where the variance becomes constant, no correlation between measurements exists. The variogram describes the degree of spatial variability between observation points as a function of distance. Spatial variability is described in terms of the nugget (variance at zero separation), range (correlation length), and the sill (ensemble variance). The variogram can also be used as a tool to characterize horizontal anisotropy in hydraulic conductivity. In an aquifer with horizontal anisotropy, hydraulic conductivity is a function of horizontal direction. For a detailed explanation of directional variogram terminology and calculation, see Deutsch and Journel (1992).

The variogram analysis was completed on logarithmically transformed hydraulic conductivity data. Directional variograms were calculated along 10 degree increments and compared to an omnidirectional variogram of the data to help delineate any directional trends. A lag width of 20,000 feet (3.8 miles) and a total lag of 120,000 feet (22.7 miles) were used. The data exhibited no distinct directional trends. Although the variogram changed with direction, closer analysis revealed that these differences were likely due to the geometry of the data, rather than any data trend. In the end, an omnidirectional variogram was retained.

Figure 4.6.4 shows the experimental variogram calculated for the Haskell-Knox-Baylor pod of the Seymour Aquifer. The range for the variogram is between 10 and 15 miles. The initial slope of the variogram appears almost linear, although this may be an artifact of the data spacing. Figure 4.6.4 also shows the model variogram fit of the data using a spherical variogram model. The equation for the spherical model is:

$$\gamma(h) = \begin{cases} C_0 + C_1\left(1.5\frac{h}{A} - 0.5\left(\frac{h}{A}\right)^3\right) & h < A \\ C_0 + C_1 & h \geq A \end{cases} \tag{4.6.1}$$

where C_0 is the nugget, C_1 is the scale (sill minus nugget), A is the range parameter, and h is the lag distance. For the model variogram shown in Figure 4.6.4, a nugget of 0.018, a scale of 0.112, and a range of 12 miles were fit to the data.

4.6.5 Spatial Distribution of Hydraulic Conductivity

The hydraulic conductivity data for the Seymour Aquifer were kriged using the variogram model described above. The resulting spatial distribution of hydraulic conductivity within the Seymour Aquifer is depicted in Figure 4.6.5. Although the kriging tends to smooth the irregularities in the sampled data, hydraulic conductivity varies approximately one order of magnitude (from 150 to 1,500 ft per day) over the aquifer.

A small topographic break which separates the Seymour Aquifer into two sections of older and younger deposits was noted by R.W. Harden and Associates (1978). They also reported that the steepest gradients in water levels were observed across this break indicating that the two units are poorly connected. Figure 4.6.6 depicts the location of the topographic break. The location was estimated using the 30 meter digital elevation map and a map depicting the approximate location of the two units in R.W. Harden and Associates (1978). A significance test was conducted to investigate whether hydraulic conductivities differ between the older and younger sections. That test indicates that hydraulic conductivities in the two sections are significantly different, with the younger units exhibiting higher hydraulic conductivities. However, only five measurements are available within the younger section, so the associated statistics are somewhat suspect.

4.6.6 Vertical Hydraulic Conductivity

No vertical hydraulic conductivity data for the hydrogeologic units in the study area were found in the literature review. The stratified nature of sediments will likely result in some degree of anisotropy in hydraulic conductivity. While horizontal hydraulic conductivity is dominated by the higher permeability sediments, vertical hydraulic conductivity will be dominated by the lower permeability strata and will tend to be lower than the horizontal hydraulic conductivity. Domenico and Schwartz (1998) list values of horizontal to vertical hydraulic conductivity ratios that range from 2 to 10 for materials similar to sediments in the study area. At the scale of the Haskell-Knox-Baylor pod of the Seymour Aquifer, higher anisotropy ratios may exist.

4.6.7 Storativity

For unconfined aquifers, the applicable storage coefficient is the specific yield which is defined as the volume of water an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in the water table (Freeze and Cherry, 1979). A literature review was conducted for specific yield of the Seymour Aquifer (Table 4.6.2). Specific yield ranged from 0.03 to 0.30 and the arithmetic means reported for two studies ranged from 0.11 to 0.15. Figure 4.6.1 shows the locations of specific yield estimates. Domenico and Schwartz (1998) list values of specific yield that range from 0.03 to 0.28 for materials similar to the sediments of the Seymour Aquifer in the active model area. Lohman (1972) gives 0.1 and 0.3 and Freeze and Cherry (1979) give 0.01 to 0.3 as general limits for the specific yield of unconfined aquifers. Originally, augmenting specific capacity values with inferred porosity data was considered. This idea was later deemed inferior to using measured data for the Seymour Aquifer and was dismissed. Specific yields were assumed to be approximately 0.15 for both of the Clear Fork and Wichita groups, which is about the middle of the values given in Freeze and Cherry (1979) for unconfined aquifers.

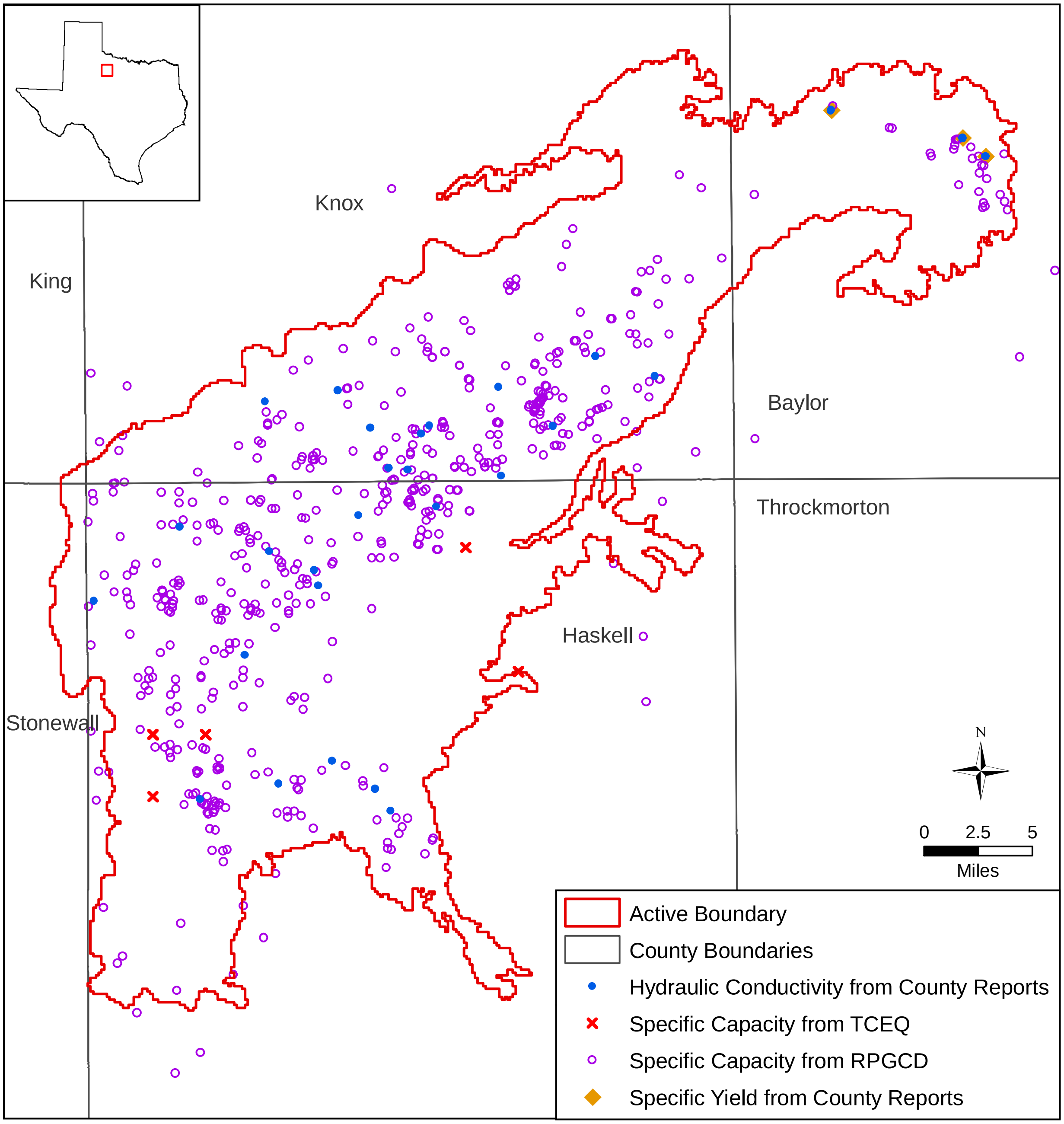
Table 4.6.1 Summary statistics for hydraulic conductivity data (feet per day) for the Seymour Aquifer and Clear Fork Formation.

Statistic	Seymour Aquifer	Clear Fork Group
Number of Samples	44	19
Arithmetic Mean	564.8	6.0
Median	342.6	2.3
Geometric Mean	386.0	2.6
Standard Deviation K	549.8	8.9
Standard Deviation Log10(K)	0.37	0.71

K = hydraulic conductivity

Table 4.6.2 Specific yield values for the Seymour Aquifer from the literature.

County	State Well Number	Specific Yield		Reference
		Point	Average	
Baylor	21-30-387	0.03	0.11	Preston (1978)
Baylor	21-30-385	0.04		
Baylor	21-22-911	0.04		
Baylor	21-22-912	0.06		
Baylor	21-22-913	0.08		
Baylor	21-21-941	0.16		
Baylor	21-21-940	0.18		
Baylor	21-30-386	0.30		
Haskell-Knox			0.15	R.W. Harden & Associates (1978)



TCEQ = Texas Commission on Environmental Quality
RPGCD = Rolling Plains Groundwater Conservation District

Figure 4.6.1 Locations and sources of hydraulic property data for the Seymour Aquifer.

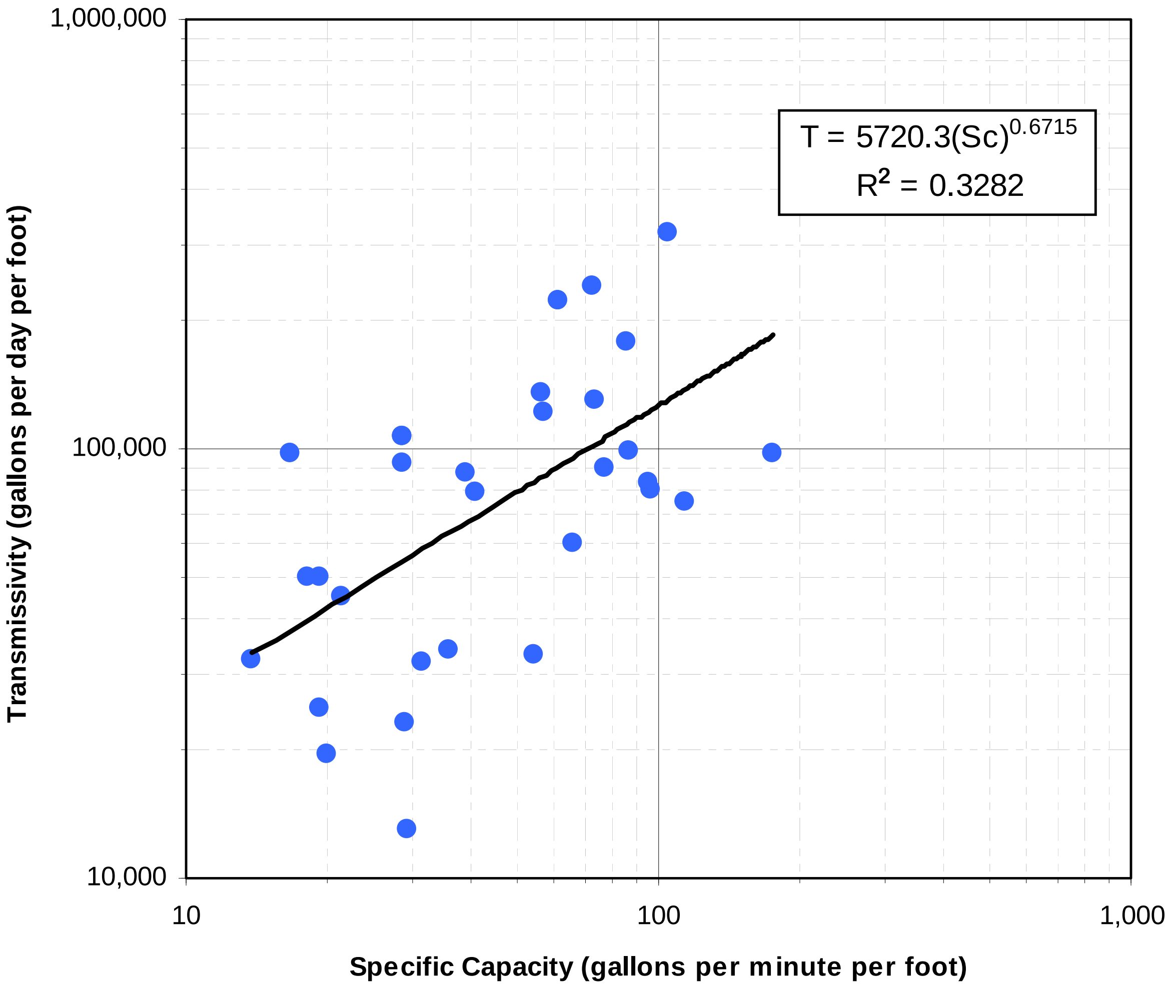


Figure 4.6.2 **Empirical correlation between transmissivity (T) and specific capacity (Sc) for the Seymour Aquifer.**
Note: (R^2 = coefficient of determination).

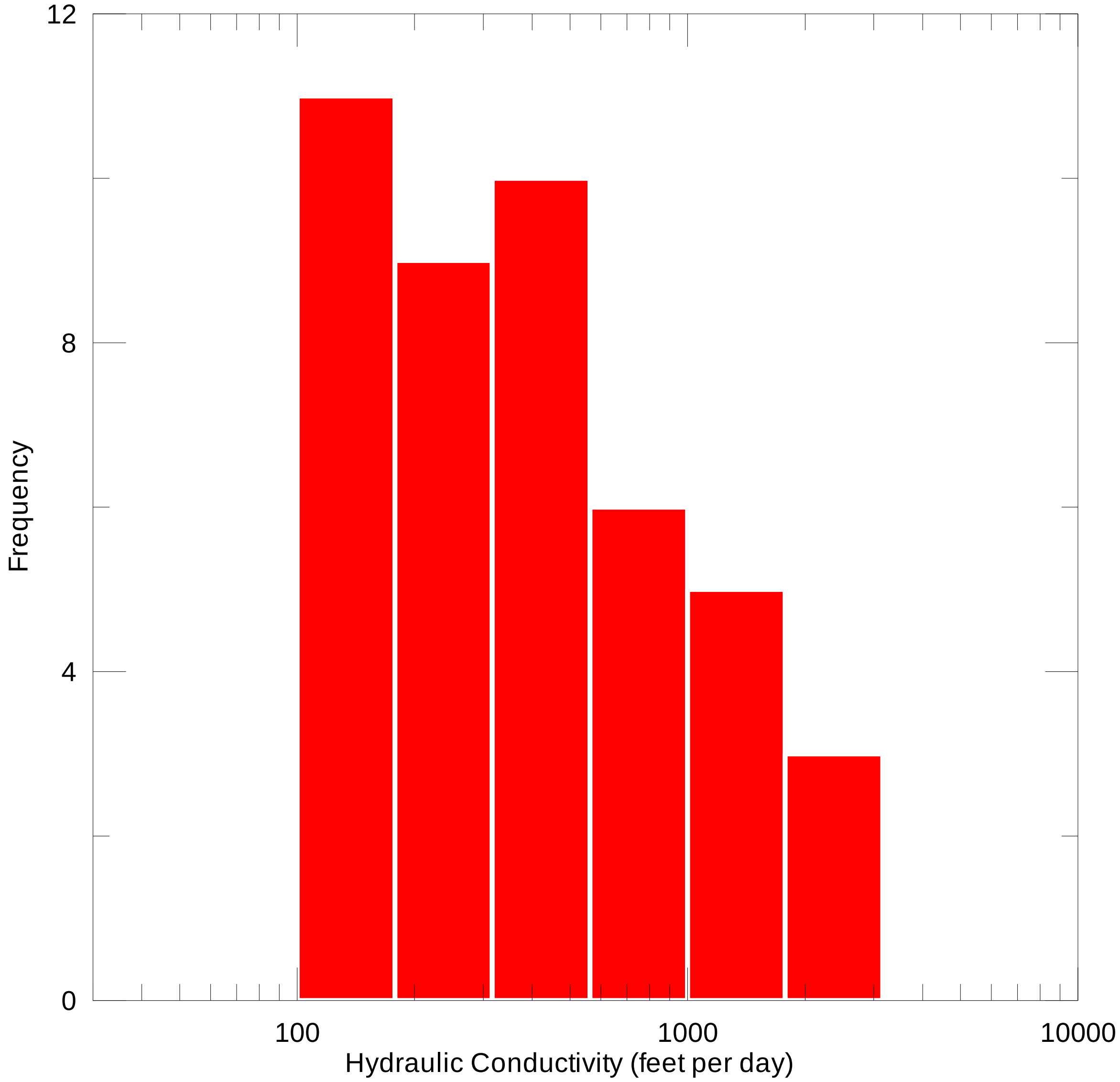


Figure 4.6.3 **Histogram of hydraulic conductivity data for the Seymour Aquifer.**

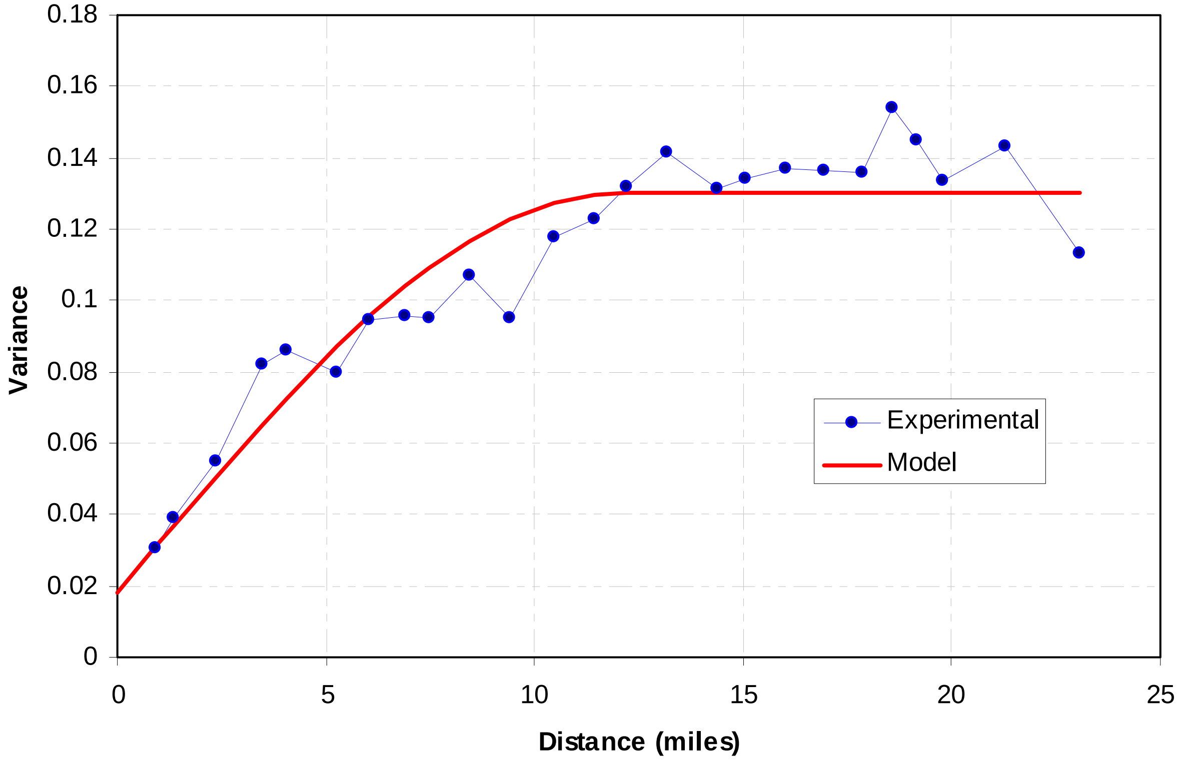


Figure 4.6.4 **Experimental variogram of log10 of hydraulic conductivity for the Seymour Aquifer.**

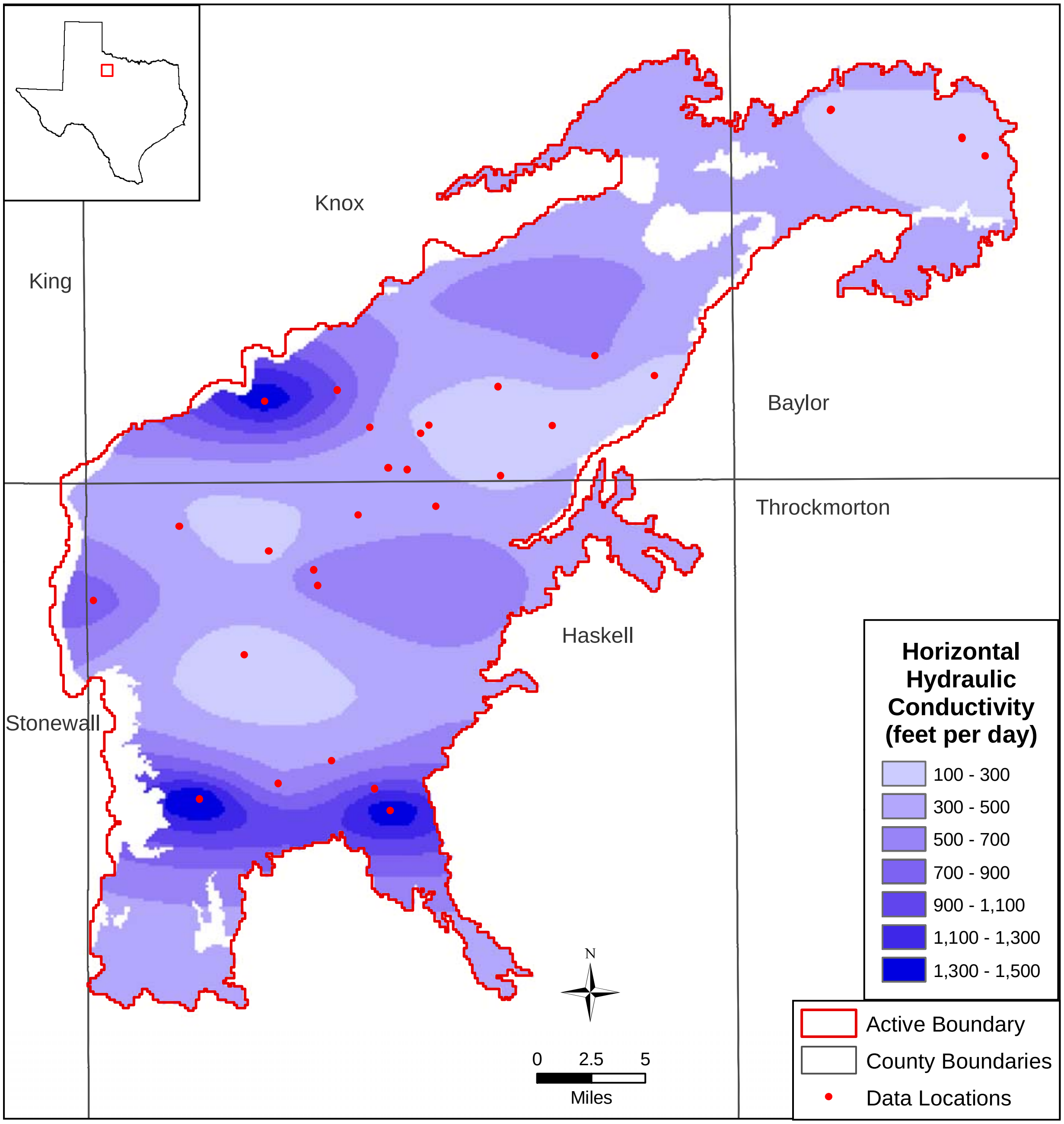


Figure 4.6.5 Kriged map of hydraulic conductivity for the Seymour Aquifer.

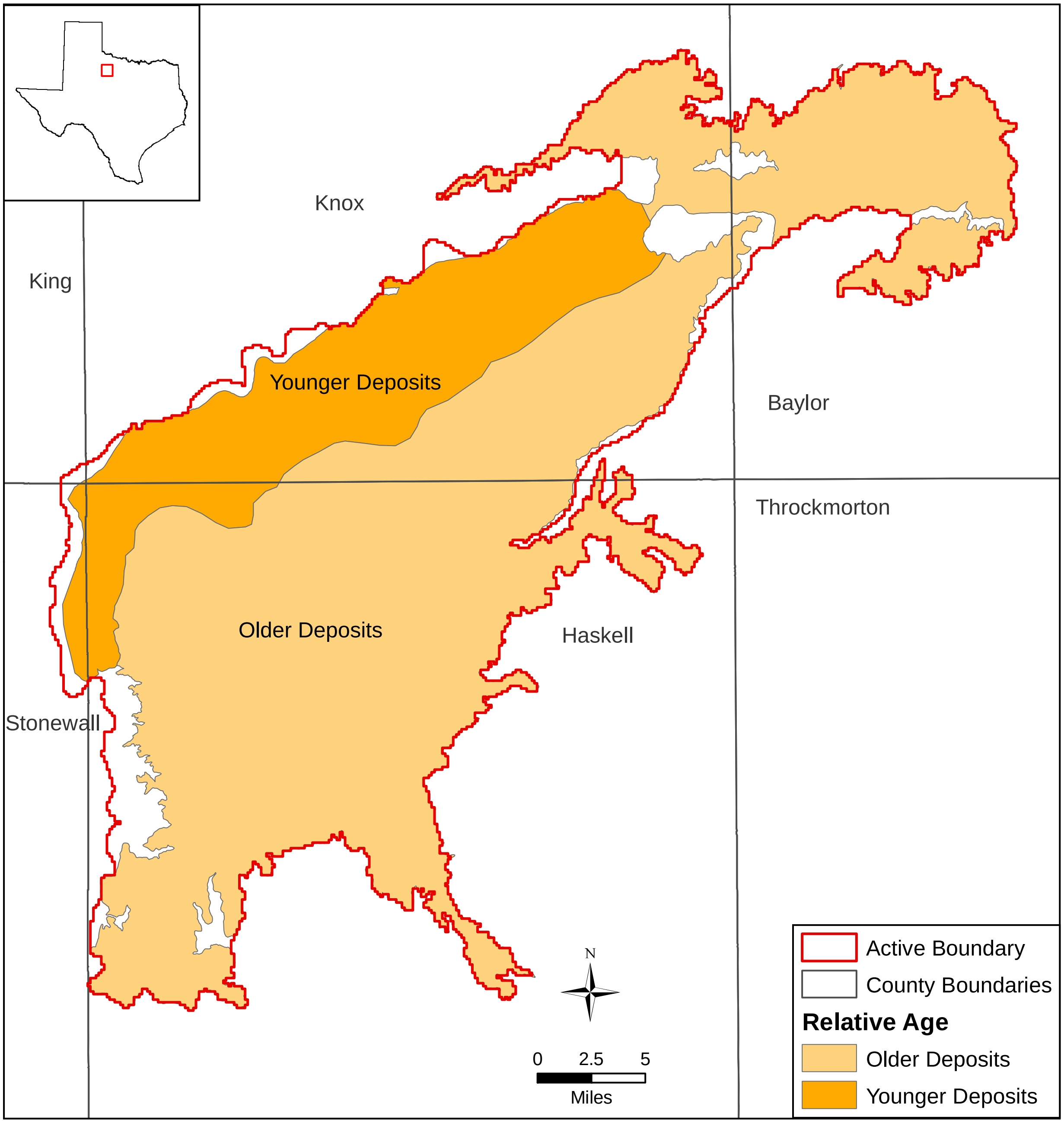


Figure 4.6.6 **Location of older and younger deposits within the Seymour Aquifer.**

4.7 Aquifer Discharge

Discharge from an aquifer can occur through either natural or man-made processes, both of which are discussed in the following sections.

4.7.1 Natural Discharge

Natural discharge from an aquifer can occur as cross-formational flow, discharge to rivers, streams, and springs, and evapotranspiration. Each of these mechanisms of natural discharge is discussed below.

The Seymour Aquifer provides baseflow to the Brazos River in Baylor County and is expected to provide baseflow to the river to some extent in western Knox and Haskell counties. In Baylor County, the Seymour Formation is connected to the Brazos River through recent alluvial deposits along the river, which are also part of the Seymour Aquifer (see Figure 2.2.2). Preston (1978) estimated discharge from the Seymour Aquifer to the Brazos River based on net gain in the river measured during a gain/loss study conducted in February 1970 (see Section 4.5.1). He calculated that the amount of yearly discharge represented by the observed gains ranged from 72.4 to 1,882.5 acre-feet (see Table 4.5.1). In western Knox and Haskell counties, the Seymour Aquifer most likely discharges directly to the Brazos River in some areas and indirectly through the Permian in other areas due to the aquifer being at a higher elevation than the river. Discharge from the Seymour Aquifer consists of groundwater flowing from the Seymour Formation to the recent alluvial sediments located along the river which then discharge to the river. In areas where the Brazos River lies below the recent alluvial deposits and, thus, the Seymour Aquifer, the aquifer does not directly provide baseflow to the river.

Although leakage from the Seymour Aquifer to the underlying Clear Fork Group is considered to be small locally, it could be significant when considered over the entire extent of the aquifer. The Clear Fork Group consists primarily of shale that has a low permeability which impedes flow. The small amount of local discharge from the Seymour Aquifer into the Clear Fork Group is supported by the difference in the chemistry between the fresh water in the Seymour Aquifer and the slightly saline water in the Clear Fork Group, however, the chemistry in the Clear Fork

Group may be more indicative of pre-development conditions than of more recent (since 1910) conditions in which recharge is considered to have increased. A discussion of cross-formational flow between the Seymour Aquifer and the Clear Fork Group is provided in Section 4.3.5.

Seeps and springs occur predominantly along the edges of the Seymour Aquifer and along the Brazos River, however, several are located a few miles from the edge, such as Rice Springs near the city of Haskell (see Section 4.5.2). Historical discharge from the springs has ranged from as high as 100 gallons per minute at a couple of springs to less than 1 gallon per minute. Most of the springs have historical discharge of between 10 and 30 gallons per minute. In general, spring discharge has declined over time.

A significant amount of natural discharge from the Seymour Aquifer occurs by evapotranspiration. R.W. Harden and Associates (1978) estimate that discharge via evapotranspiration is considerably larger than discharge via springs and seeps. They considered the areas containing dense phreatophytes as the main areas where natural discharge by evapotranspiration occurs. The figure in R.W. Harden and Associates (1978) showing areas of natural discharge from the Seymour Aquifer is reproduced as Figure 4.5.6. That figure shows areas on the Seymour Aquifer that contain dense phreatophytes.

Direct evaporation from the water table is a function of the depth of the water table, the type of material in the unsaturated zone, the type of climate, and the coverage of the ground surface. Evaporation increases with decreasing depth to the water table, homogeneous coarse-grain sediments, hotter and drier climates, and bare soil. White (1932) conducted a field experiment in Escalante Valley, Utah to measure groundwater evaporation from bare soils consisting of clay, clay loam, and loam during the months of April through October. He found evaporation rates ranging from 0.1 to 1.3 feet per year for water-table depths ranging from 2 to 6.8 feet for the clay and clay loam soils and evaporation rates ranging from 0.9 to 3.4 feet per year for water-table depths ranging from 2.4 to 3.6 feet for the loam soil. White (1932) indicates that the high evaporation rates observed for the loam soil may have been due to a problem with the experimental set up for that soil. Preliminary data on water-table evaporation at a field site in the Middle Rio Grande bosque in New Mexico indicates evaporation on the order of 1 to 3 feet per year for water-table depths of 1 to 1.5 feet, respectively (Stormont and Coonrod, 2004). Rose and others (2005) obtained steady-state evaporation rates of 1.6 to 0.4 feet per year for water-table depths of 1 to 2.3 feet, respectively. They conducted their experiment on a bare sandy loam soil with a shallow saline water table under high isothermal evaporative demand. Evaporation from the Seymour Aquifer is expected to be less than that measured for bare soils since it is covered by vegetation during the hottest months of the year. In addition, the soil in the upper portion of the Seymour Aquifer is typically fine grained and heterogeneous, which also reduces groundwater evaporation. Evaporation from the Seymour Aquifer is expected to be small relative to transpiration by plants.

In summary, significant avenues for outflow include baseflow into streams, cross-formational discharge to the Clear Fork Group. Evapotranspiration and spring discharge together are expected to constitute a significant amount of outflow in riparian areas, from the edges of the Seymour aquifer, and from areas with dense phreatophyte growth.

4.7.2 Aquifer Discharge through Pumping

Pumping discharge for each county in the active model area was developed for the transient model. Pumping during the transient model calibration period of 1980 through 1997 was obtained from the TWDB pumping database. Pumping data for the time period prior to 1980 were found in Ogilbee and Osborne (1962), Preston (1978), R.W. Harden and Associates (1978), and TWDB (1981).

4.7.2.1 Methodology

The methodologies used to estimate pumping during the transient model calibration period and prior to 1980 are described in the following sections.

Transient Model Calibration Period Pumping

Estimates of groundwater pumping for the transient model calibration period (1980 through 1997) are provided by the TWDB as master pumpage tables contained in a pumpage geodatabase. The six water use categories defined in the TWDB database are municipal, manufacturing, power generation, mining, livestock, and irrigation. Each water use record in the database carries an aquifer identifier that was used to select pumping records for the Seymour

Aquifer. Rural domestic pumping, which consists primarily of unreported domestic water use, was estimated based on population density data provided by the TWDB.

The TWDB municipal, manufacturing, mining, and power pumping estimates are based on actual water use records reported by the water users. The pumpage geodatabase also includes historical annual pumping estimates for livestock and irrigation for each county-basin. A county-basin is a geographic unit created by the intersection of county and river basin boundaries. For example, Baylor County, which is intersected by both the Brazos River basin and the Red River basin, contains two county-basins.

Reported pumping for municipal, manufacturing, mining, and power water uses was matched to the specific wells from which it was pumped to identify the withdrawal location in the aquifer (latitude, longitude, and depth above mean sea level) based on the well's reported properties. When more than one well is associated with a given water user, groundwater withdrawals were divided evenly among those wells.

Livestock pumping totals within each county-basin was distributed uniformly over the rangeland within the county-basin, based on land use maps, using the categories "shrubland", "grassland/herbaceous", and "pasture/hay". Irrigation pumping within each county-basin was distributed between wells in the TWDB database (TWDB, 2008c) identified as having a primary use of irrigation.

Rural domestic pumping was distributed based on United States census block population density (Figure 4.7.1) in non-urban areas. The TWDB has provided a polygon feature class of census blocks, based on the 1990 United States census, and a table of factors for converting rural population density into annual groundwater use. Although these rural domestic use factors are uncertain, this uncertainty is not significant since rural domestic pumping accounts for less than one-half a percent of total Seymour Aquifer pumping. Urban areas were excluded from rural population calculations and groundwater pumpage.

Pre-1980 Pumping

Because detailed pumping data are not available prior to the transient model calibration period, a literature search was conducted to obtain historical pumping data. Those data are summarized in Table 4.7.1.

Groundwater from the Seymour Aquifer was predominately used for municipal, domestic, and livestock purposes prior to 1950 (Ogilbee and Osborne, 1962; R.W. Harden and Associates, 1978). R.W. Harden and Associates (1978) provide an estimate of total pumpage from the Seymour Aquifer in Haskell and Knox counties every 10 years between 1900 and 1940. They also provide estimates for municipal and irrigation pumpage every year from 1950 through 1976. Their estimates of irrigation pumpage were developed based on records of electricity use for irrigation and an approximation of the number of gallons pumped per kilowatt hour for sprinkler systems and open discharge wells and the historical use of sprinklers in the counties. For irrigation wells powered by butane and natural gas during the time period from 1950 through 1976, R.W. Harden and Associates (1978) estimated their pumpage based on the number of wells. Their estimates of municipal pumpage for 1950 through 1976 were developed using data from individual towns and records from the Texas Department of Water Resources (former name for the TWDB). The historical pumpage data obtained from R.W. Harden and Associates (1978) is summarized in Table 4.7.1.

Ogilbee and Osborne (1962) estimate that irrigation pumpage from the Seymour Aquifer in Haskell and Knox counties was less than 500 acre-feet per year from 1938, when three irrigation wells were dug, through 1951. Using a duty-of-water figure obtained in 1956, they estimated irrigation pumping for 1952 to 1955. They estimated irrigation pumpage for the year 1956 based on estimates of water pumped per unit power consumed for selected wells powered by electricity. They also provide an estimate of pumpage for purposes other than irrigation for the year 1956. The historical pumpage data obtained from Ogilbee and Osborne (1962) are summarized in Table 4.7.1.

Preston (1978) calculated irrigation pumping from the Seymour Formation in western Baylor County from the city of Seymour westward to the Baylor-Knox county line for the years 1952 through 1969 "by applying production figures from power-yield tests ". Estimates of municipal pumpage for 1955 through 1969 and estimates for industrial and rural domestic/livestock pumpage for 1969 are also provided by Preston (1978). The historical pumpage data obtained from Preston (1978) are summarized in Table 4.7.1.

In 1958, a cooperative agreement was made between the Soil Conservation Service of the United States Department of Agriculture, the Texas State Soil and Water Conservation Board, and the TWDB and its predecessor agencies to inventory irrigation in Texas. Since that time, irrigation in Texas has been inventoried on a county-by-county basis about every five years. The inventories include a break down of irrigation with surface water and with groundwater and are obtained through inventory forms and local field data gathering. TWDB (1981) provides the inventory summary for the years 1958, 1964, 1969, 1974, and 1979. Field personnel from the Soil Conservation Service involved with the irrigation inventories on the local level in 1979 estimate that the accuracy of their estimates is within 5 to 10 percent (TWDB, 1981). Irrigation by groundwater for these years in Haskell, Knox, and Baylor counties is summarized in Table 4.7.1. TWDB (1981) reports irrigation pumpage for entire counties and does not indicate which aquifer(s) supply the irrigation water. For Haskell and Knox counties, all groundwater used for irrigation purposes likely comes from the portion of the Seymour Aquifer included in the study area. All of the Seymour Aquifer in Haskell County is included in this study, and irrigation pumpage in the small portion of the Seymour Aquifer in northern Knox County not included in this study is likely small. This assumption is considered to be reasonable by the Rolling Plains Groundwater Conservation District because the quality of water in the small pod of the Seymour Aquifer in northern Knox County is poor (McGuire, 2009). For Baylor County, however, it is likely that some irrigation occurs in portions of the Seymour Aquifer not included in this model.

The historical pumpage data presented above and summarized in Table 4.7.1 was used to estimate pumpage for Haskell, Knox, and Baylor counties for the years prior to 1980.

4.7.2.2 Pumping Plots and Tables

Table 4.7.2 provides the total groundwater withdrawals by county for the Haskell-Knox-Baylor pod of the Seymour Aquifer for the years 1980, 1985, 1990, 1995, and 1997. A bar chart of total pumping by category from 1980 through 1997 is provided in Figure 4.7.2. In 1997, about

97.1 percent of pumpage from the Seymour Aquifer was used for irrigation purposes, about 2.0 percent was used for municipal purposes, about 0.36 percent was used for rural domestic purposes, about 0.45 percent was used for livestock purposes, and none was used for mining purposes. Groundwater from this pod of the Seymour Aquifer is not used for manufacturing or power purposes. Total pumpage from the Seymour Aquifer shows a steady declined from a high of 94,701 acre-feet per year in 1980 to 32,653 acre-feet per year in 1987. Pumpage was also low in 1988 with 34,841 acre-feet per year and then jumped significantly to 64,177 acre-feet per year in 1989. Another steady decline is observed between 1989 and 1993. Pumpage was steady in 1994, 1995, and 1996 at a little over 60,000 acre-feet per year and then decreased to 44,945 acre-feet per year in 1997. Figure 4.7.3 shows the 1980 through 1997 average pumping demands by county for the Haskell-Knox-Baylor pod of the Seymour Aquifer. This figure shows that pumpage in Baylor County is significantly less than that in Haskell and Knox counties. Pumpage in Stonewall County is the least among the four counties due to its relatively small area in the model.

Tables 4.7.3 through 4.7.7 summarize pumping for each county by category for the years 1980, 1985, 1990, 1995, and 1997. Notice that a table for manufacturing and power pumping is not provided since groundwater from this portion of the aquifer was not used for those purposes during this time period. Irrigation pumpage is significantly higher in Haskell and Knox counties than in Baylor and Stonewall counties (Table 4.7.3). The highest pumpage for municipal purposes is in Baylor County (Table 4.7.4). Rural domestic pumpage is higher in Baylor and Knox counties than in Haskell and Stonewall counties (Table 4.7.5). The amount of groundwater pumped for livestock is about the same for Baylor, Haskell and Knox counties and lower in Stonewall County (Table 4.7.6). Pumpage for mining occurred only in Stonewall County (Table 4.7.7). Figures 4.7.4 through 4.7.7 show pumpage by category from 1980 through 1997 for Baylor, Haskell, Knox and Stonewall counties, respectively. As previously stated, pumpage for irrigation purposes dominates in Haskell and Knox counties and is a large percentage of total pumping in Baylor and Stonewall counties.

Table 4.7.1 Available data on historical pumpage from the Seymour Aquifer between 1900 and 1979.

Year	Baylor County					Haskell and Knox Counties					Haskell County	Knox County
	Preston (1978)				TWDB (1981)	Ogilbee and Osborne (1962)		R.W. Harden and Associates (1978)			TWDB (1981)	TWDB (1981)
	portion of the Seymour Formation located west of the city of Seymour to the Knox-Baylor county line (i.e., portion of Seymour Aquifer considered by this study)				entire county	portion of Seymour Aquifer considered by this study		portion of Seymour Aquifer considered by this study			entire county	entire county
	Estimated Irrigation Pumpage (AF)	Estimated Municipal Pumpage (AF)	Estimated Industrial (AFY)	Estimated Rural Domestic and Livestock (AFY)	Irrigation Pumpage (AF)	Estimated Irrigation Pumpage (AF)	Estimated Pumpage for Other Purposes (AF)	Estimated Irrigation Pumpage (AF)	Estimated Public Supply Pumpage (AF)	Estimated Total Pumpage (AF)	Irrigation (AF)	Irrigation (AF)
1900										200		
1910										400		
1920										400		
1930										900		
1940						<500				1,200		
1950						<500		100	1,200	1,300		
1951						<500		900	1,200	2,100		
1952	60					9,000		6,700	1,200	7,900		
1953	390					13,000		9,900	1,200	11,100		
1954	650					22,000		16,800	1,200	18,000		
1955	880	450				45,000		34,800	1,200	36,000		
1956	3,130	820				76,500	2,900	63,800	1,200	65,000		
1957	2,180	640						46,800	1,300	48,100		
1958	1,380	610			3,371			34,500	1,800	36,300	29,533	19,276
1959	2,750	500						17,900	1,600	19,500		
1960	2,740	670						54,600	1,800	56,400		
1961	1,550	580						36,200	1,600	37,800		
1962	2,990	590						60,200	1,900	62,100		
1963	3,580	640						56,800	1,800	58,600		
1964	5,060	680			6,039			64,400	1,500	65,900	66,075	34,894
1965	4,990	680						53,000	2,100	55,100		
1966	4,850	630						51,100	2,000	53,100		
1967	3,850	660						51,600	1,900	53,500		
1968	2,100	670						26,500	1,700	28,200		
Jan-69	3,770	42.4	150	350	6,108			32,000	1,700	33,700	37,696	49,874
Feb-69		37.4										
Mar-69		36.5										
Apr-69		51.4										

Table 4.7.1, continued

Year	Baylor County					Haskell and Knox Counties					Haskell County	Knox County
	Preston (1978)				TWDB (1981)	Ogilbee and Osborne (1962)		R.W. Harden and Associates (1978)			TWDB (1981)	TWDB (1981)
	portion of the Seymour Formation located west of the city of Seymour to the Knox-Baylor county line (i.e., portion of Seymour Aquifer considered by this study)				entire county	portion of Seymour Aquifer considered by this study		portion of Seymour Aquifer considered by this study			entire county	entire county
	Estimated Irrigation Pumpage (AF)	Estimated Municipal Pumpage (AF)	Estimated Industrial (AFY)	Estimated Rural Domestic and Livestock (AFY)	Irrigation Pumpage (AF)	Estimated Irrigation Pumpage (AF)	Estimated Pumpage for Other Purposes (AF)	Estimated Irrigation Pumpage (AF)	Estimated Public Supply Pumpage (AF)	Estimated Total Pumpage (AF)	Irrigation (AF)	Irrigation (AF)
May-69		56.3										
Jun-69		71.5										
Jul-69		133.4										
Aug-69		128.4										
Sep-69		43.1										
Oct-69		39.5										
Nov-69		51.7										
Dec-69		36.4										
1970								41,900	1,900	43,800		
1971								51,200	1,700	52,900		
1972								34,800	1,500	36,300		
1973								24,000	1,600	25,600		
1974					5,364			63,600	1,600	65,200	41,639	44,705
1975								25,100	1,600	26,700		
1976								39,100	1,700	40,800		
1977												
1978												
1979					794						38,013	51,283

AF = acre-feet
AFY = acre-feet per year
TWDB = Texas Water Development Board

Table 4.7.2 Total pumping in acre-feet per year by county for 1980, 1985, 1990, 1995, and 1997.

County	Year				
	1980	1985	1990	1995	1997
Baylor	6,705	2,444	2,395	1,337	1,091
Haskell	39,391	11,074	22,211	32,528	26,658
Knox	48,538	30,910	32,490	31,598	17,002
Stonewall	67	95	146	392	193
Total	94,701	44,524	57,242	65,855	44,945

Table 4.7.3 Irrigation pumping in acre-feet per year by county for 1980, 1985, 1990, 1995, and 1997.

County	Year				
	1980	1985	1990	1995	1997
Baylor	5,748	1,479	1,574	457	389
Haskell	38,906	10,697	21,873	32,190	26,297
Knox	48,349	30,695	32,323	31,365	16,795
Stonewall	53	80	137	379	182
Total Irrigation	93,056	42,951	55,907	64,391	43,663

Table 4.7.4 Municipal pumping in acre-feet per year by county for 1980, 1985, 1990, 1995, and 1997.

County	Year				
	1980	1985	1990	1995	1997
Baylor	786	846	690	734	622
Haskell	429	332	275	247	239
Knox	39	46	0	44	57
Stonewall	0	0	0	0	0
Total Municipal	1,254	1,224	965	1,024	917

Table 4.7.5 Rural domestic pumping in acre-feet per year by county for 1980, 1985, 1990, 1995, and 1997.

County	Year				
	1980	1985	1990	1995	1997
Baylor	108	41	39	36	34
Haskell	18	21	20	21	15
Knox	121	129	122	115	112
Stonewall	1	1	1	1	0
Total Rural Domestic	248	192	182	173	161

Table 4.7.6 Livestock pumping in acre-feet per year by county for 1980, 1985, 1990, 1995, and 1997.

County	Year				
	1980	1985	1990	1995	1997
Baylor	64	78	93	110	46
Haskell	38	24	43	70	108
Knox	29	41	45	74	38
Stonewall	8	12	8	13	11
Total Livestock	139	155	189	267	203

Table 4.7.7 Mining pumping in acre-feet per year by county for 1980, 1985, 1990, 1995, and 1997.

County	Year				
	1980	1985	1990	1995	1997
Baylor	0	0	0	0	0
Haskell	0	0	0	0	0
Knox	0	0	0	0	0
Stonewall	4	3	0	0	0
Total Mining	4	3	0	0	0

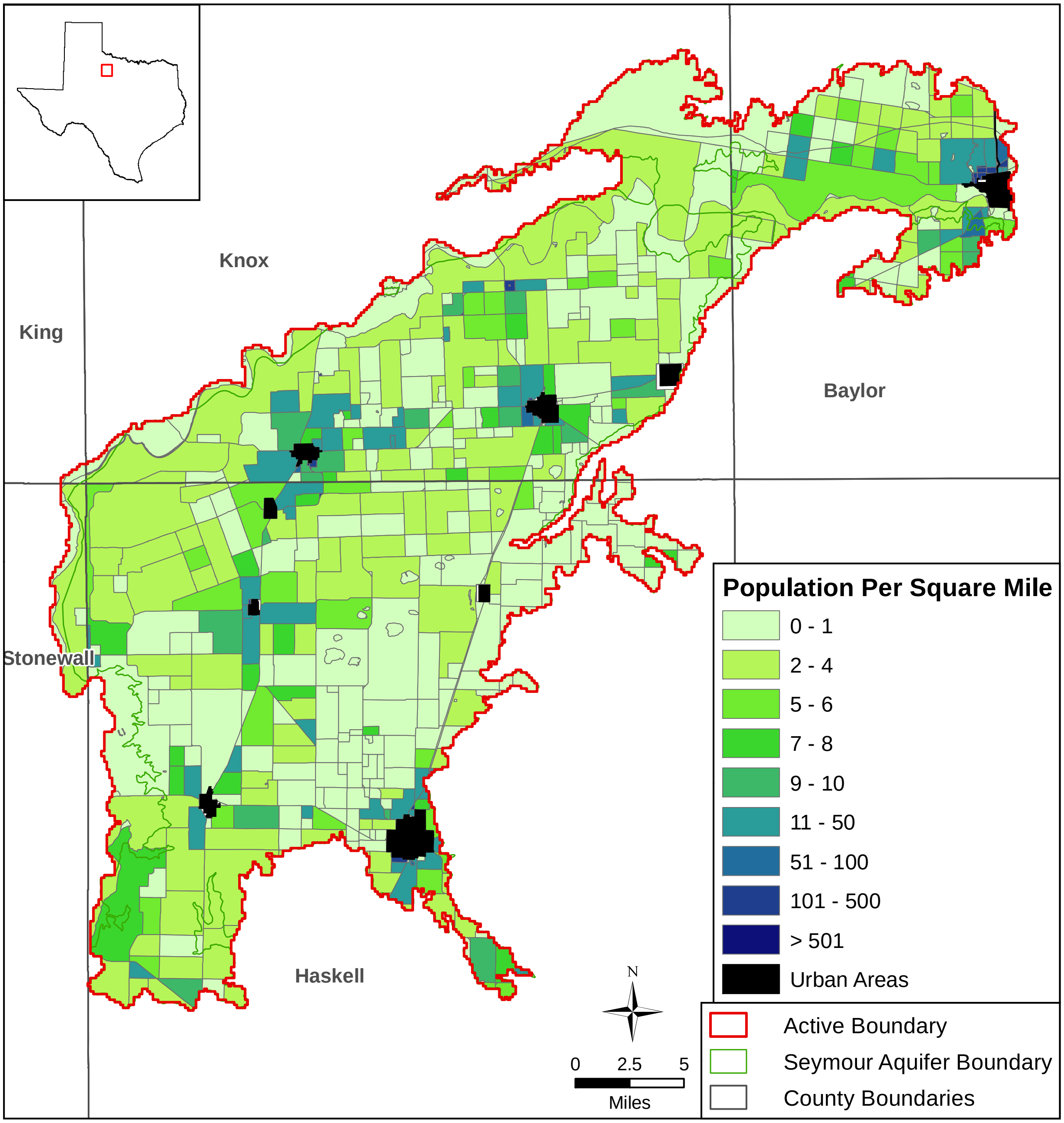


Figure 4.7.1 **Population density for the model area.**

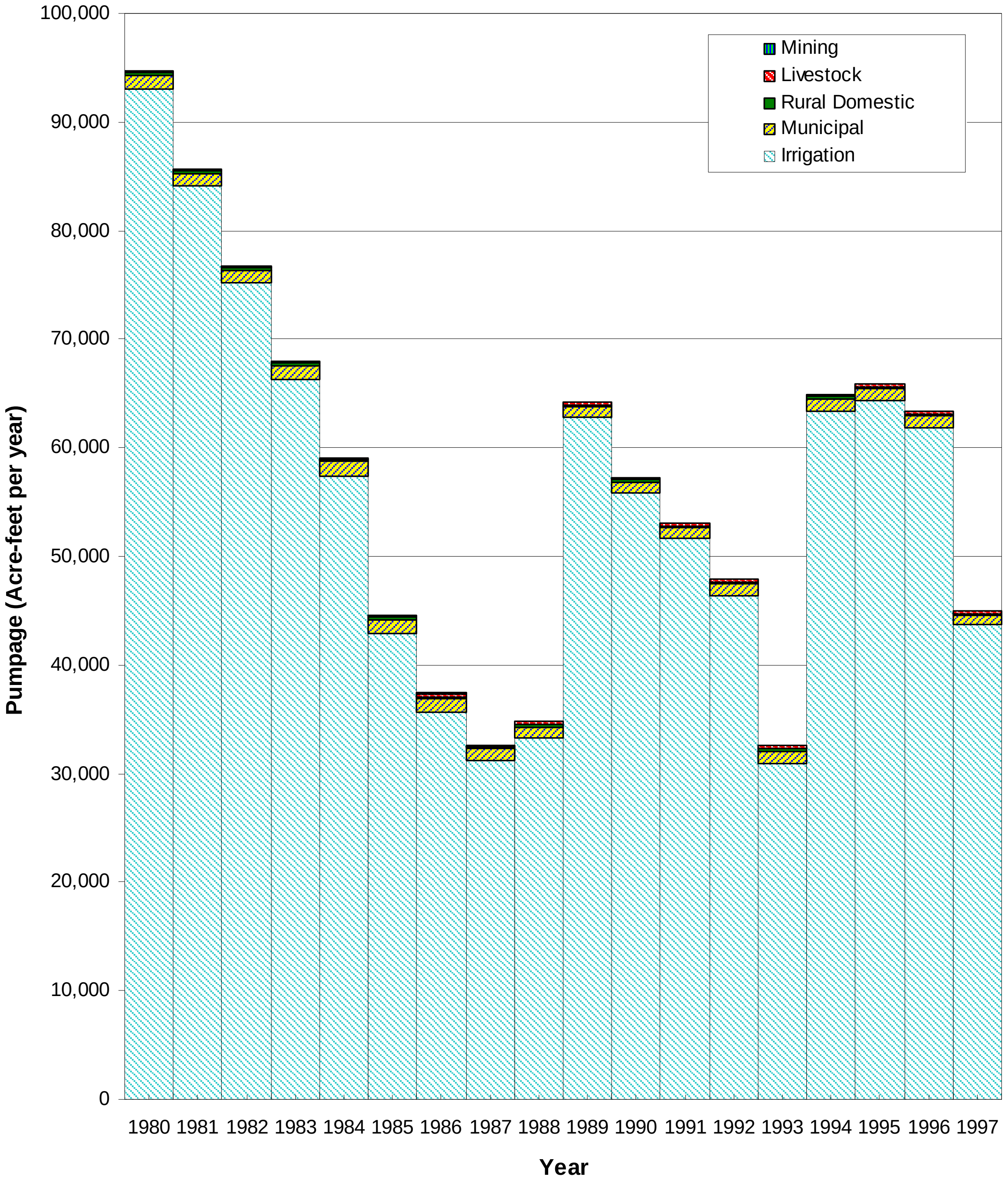


Figure 4.7.2 **Total groundwater withdrawals from the Haskell-Knox-Baylor pod of the Seymour Aquifer by category.**

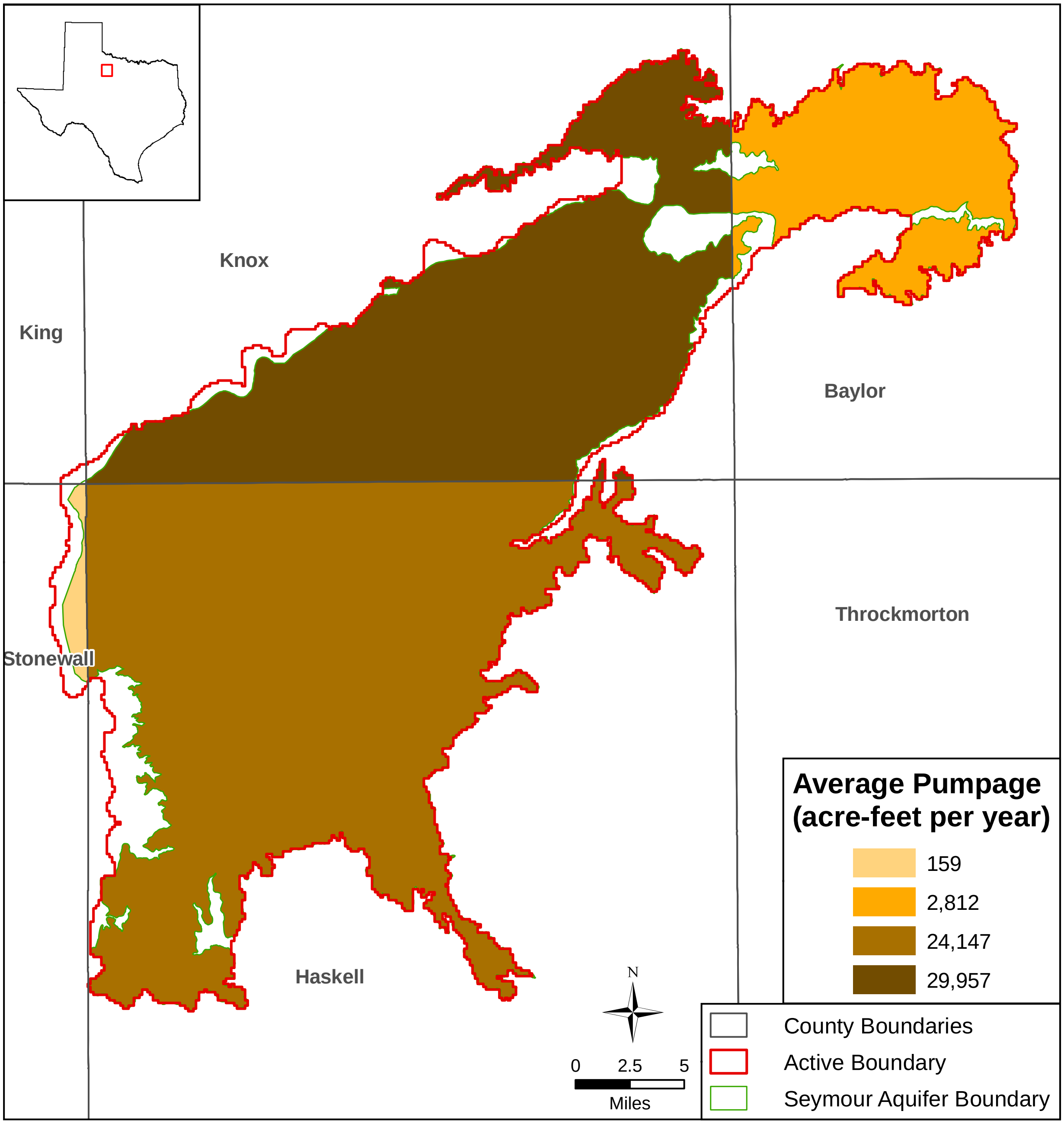


Figure 4.7.3 **Yearly average pumpage from the Haskell-Knox-Baylor pod of the Seymour Aquifer for 1980 through 1997.**

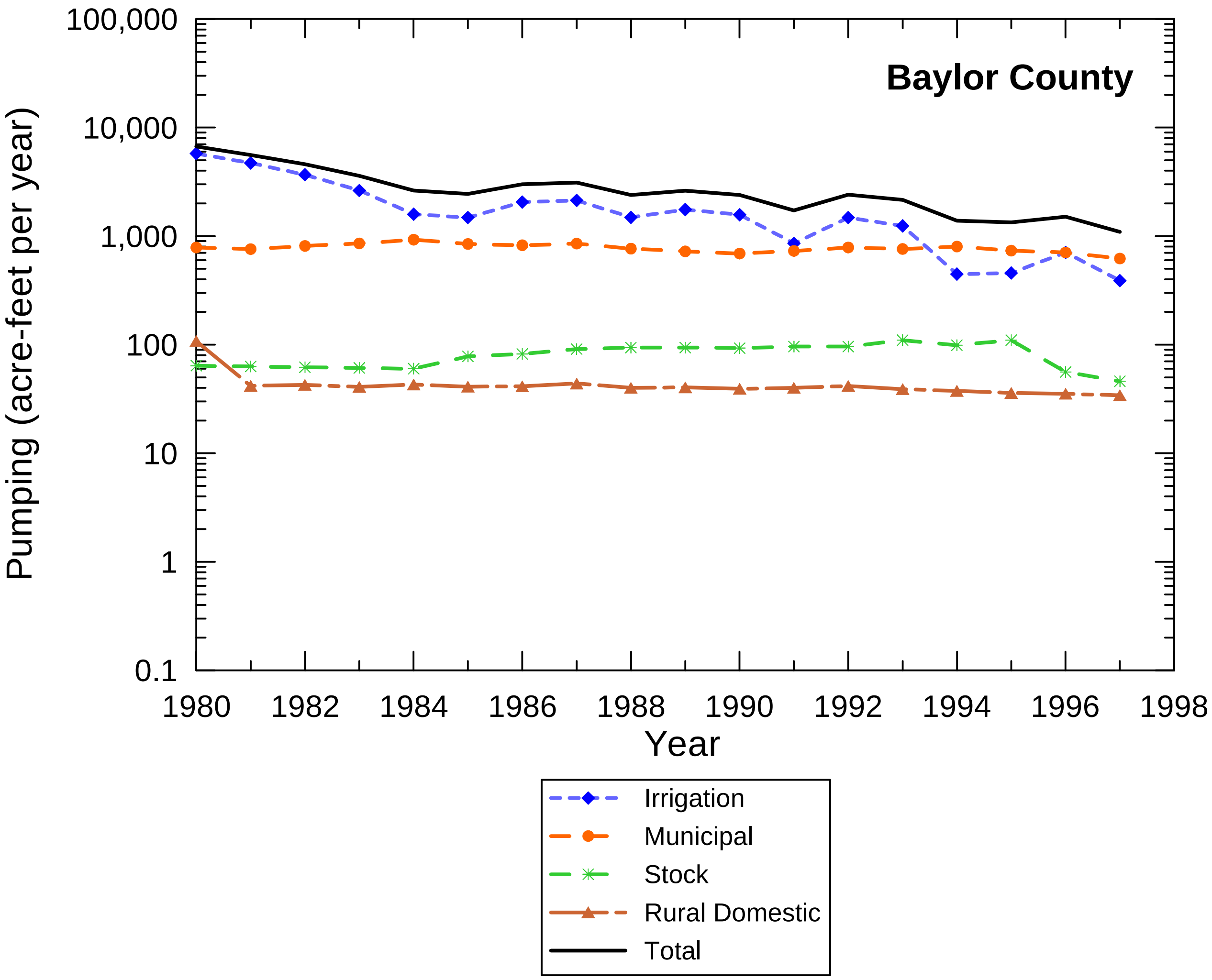


Figure 4.7.4 **Groundwater withdrawals from 1980 through 1997 for the portion of the Seymour Aquifer in Baylor County considered by this study.**

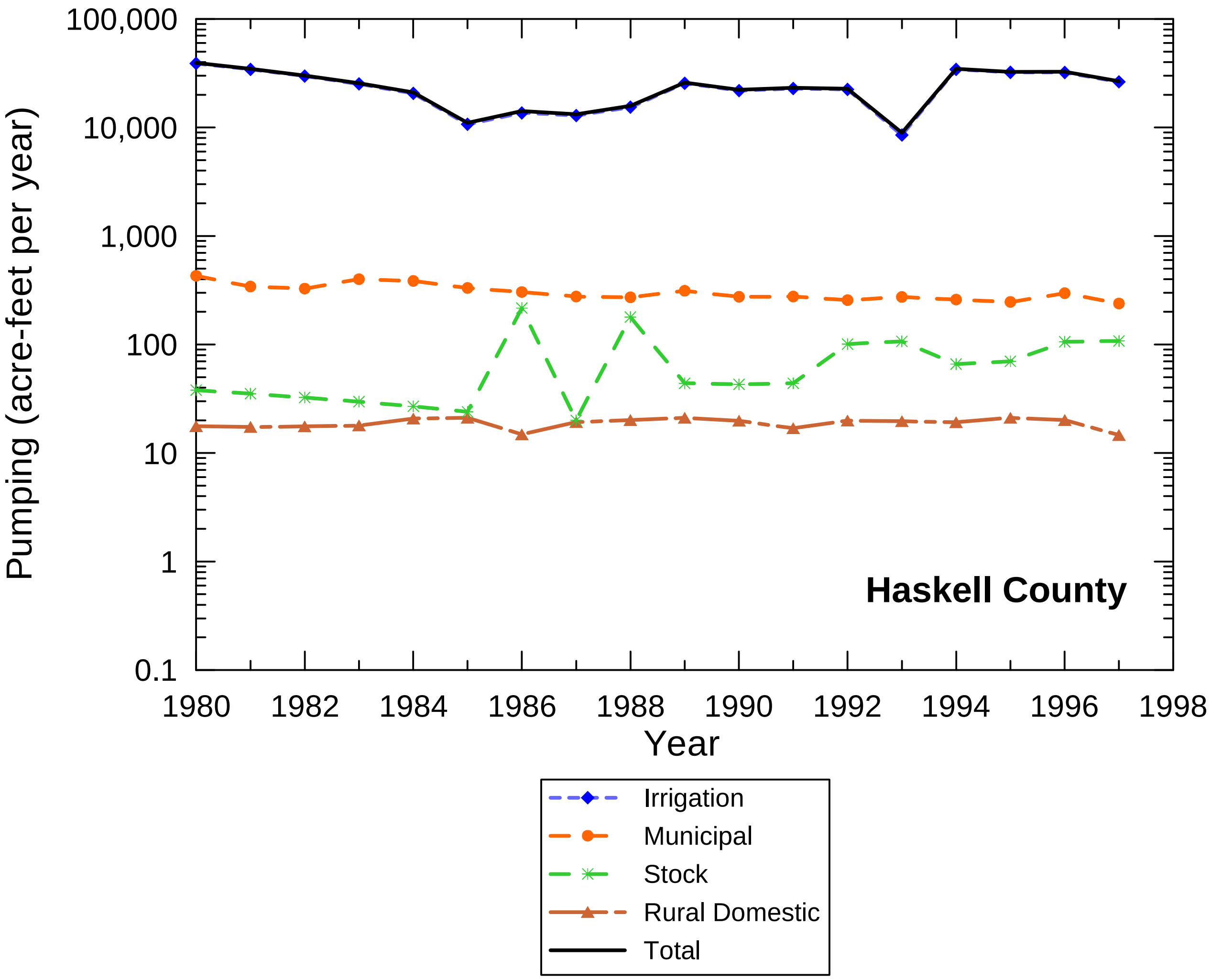


Figure 4.7.5 **Groundwater withdrawals from 1980 through 1997 for the Seymour Aquifer in Haskell County.**

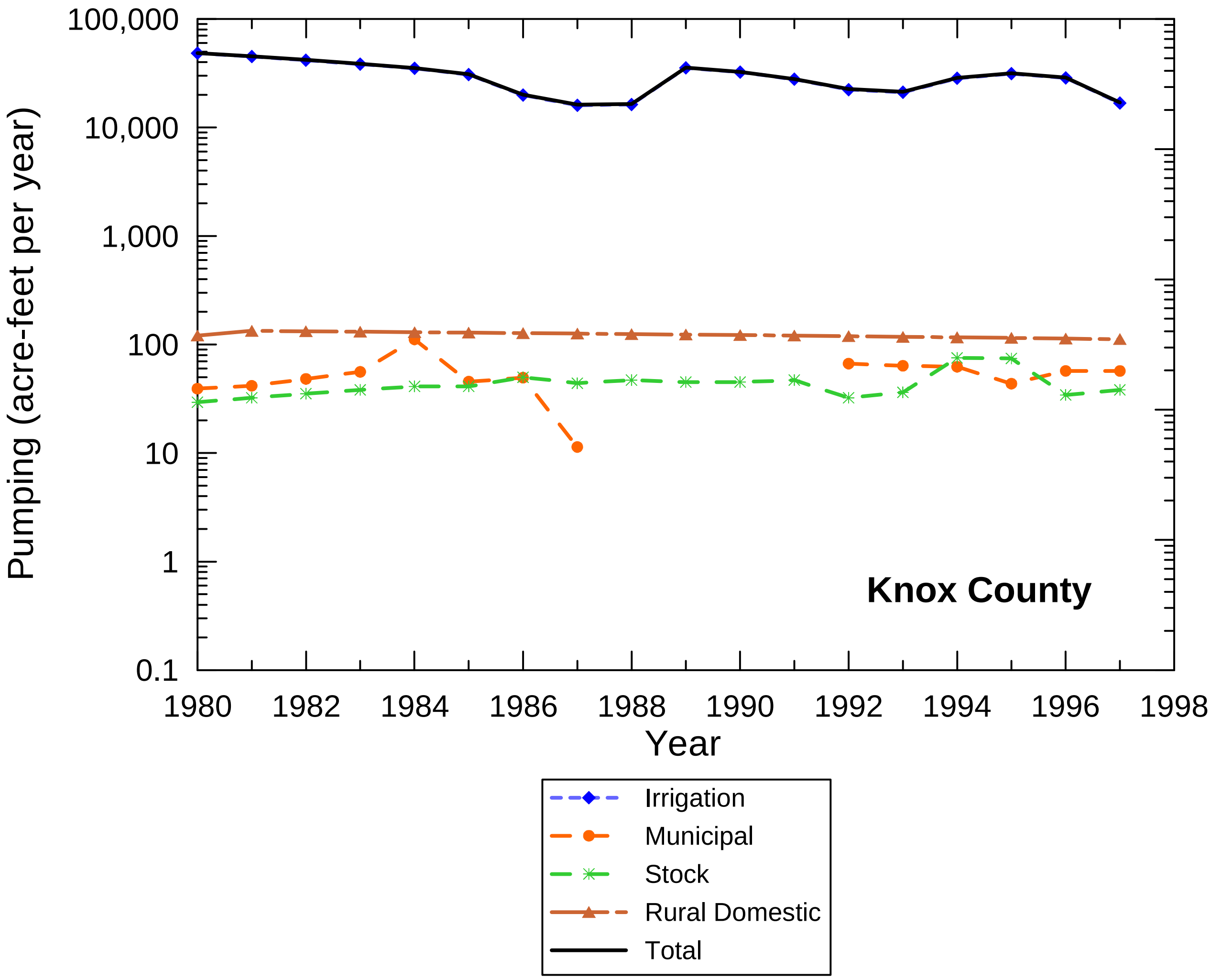


Figure 4.7.6 **Groundwater withdrawals from 1980 through 1997 for the portion of the Seymour Aquifer in Knox County considered by this study.**

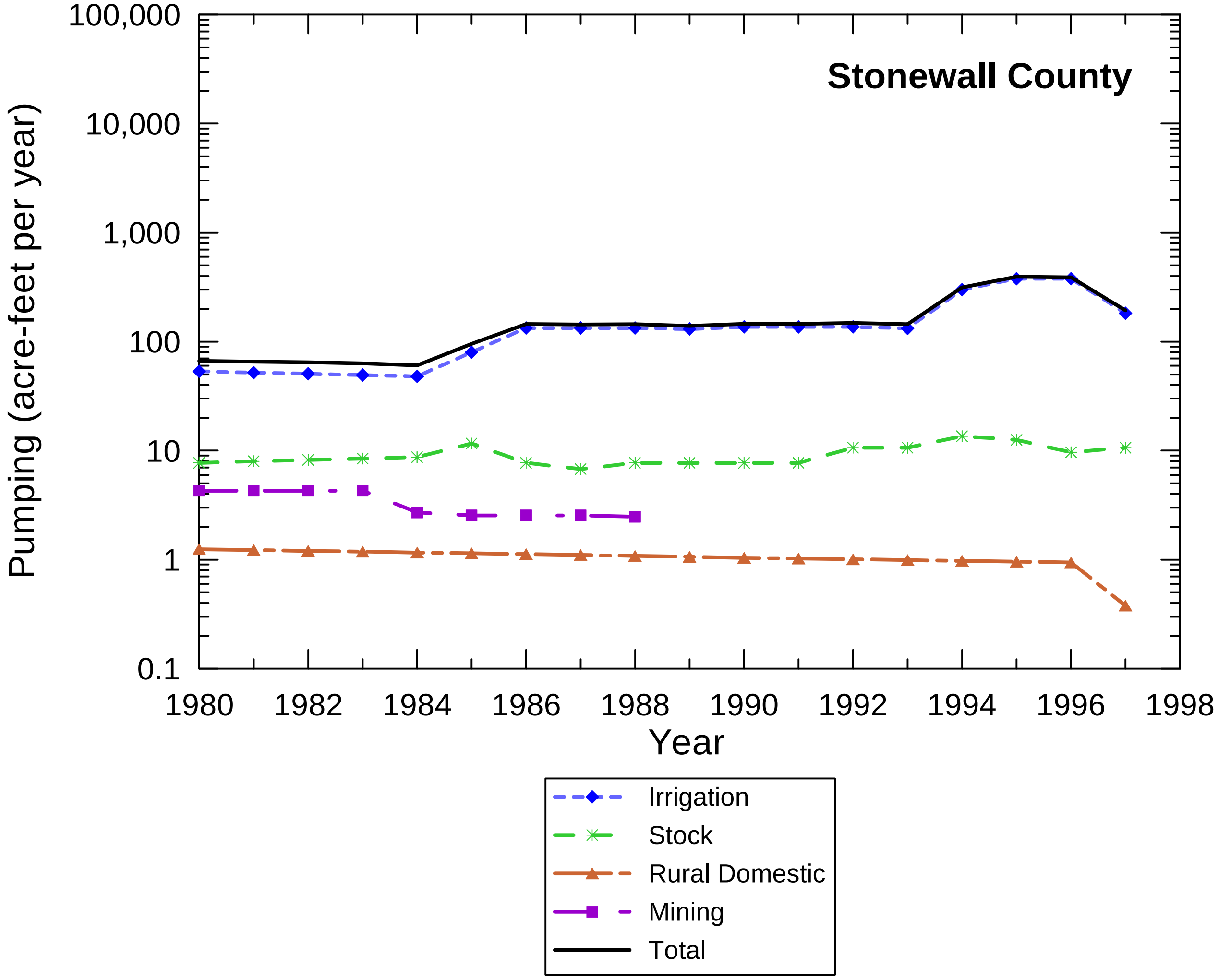


Figure 4.7.7 **Groundwater withdrawals from 1980 through 1997 for the portion of the Seymour Aquifer in Stonewall County considered by this study.**

4.8 Water Quality in the Seymour Aquifer

Groundwater in the Haskell-Knox-Baylor pod of the Seymour Aquifer was evaluated for its quality as a drinking water supply and for irrigation of crops by comparing the measured chemical and physical properties of the water to screening levels. Water quality measurements were retrieved for the entire available historical record, 1906 through 2006, from the TWDB groundwater database (TWDB, 2009c).

4.8.1 Previous Studies

The quality of groundwater in the Seymour Aquifer is discussed briefly by Ogilbee and Osborne (1962) in their report on groundwater resources in Haskell and Knox counties. Preston (1978) provides a discussion on water quality and possible sources of contamination of groundwater in the Seymour Aquifer in his report on the occurrence and quality of groundwater in Baylor County. R.W. Harden and Associates (1978) provide a comprehensive look at the quality of groundwater in the Seymour Aquifer in Haskell and Knox counties and pollution or the potential for pollution of groundwater in the aquifer due to oil field activities, septic tanks and cesspools, sewage treatment plant discharge, landfills and dumps, and agricultural operations. They estimated that, as of 1977, about 2 percent of the groundwater in the Seymour Aquifer was polluted. The majority of this pollution was the result of historical practices and not due to significant, current sources of pollution. Of the polluted groundwater, R.W. Harden and Associates (1978) estimated that 75 percent was polluted by oil field disposal pits, 20 percent by injection wells or unplugged holes, 4 percent by septic tanks, and 1 percent by all other sources.

4.8.2 Data Sources and Methods of Analysis

The TWDB groundwater database (TWDB, 2009c) is the source of water-quality data for groundwater in the Seymour Aquifer. Chemical analyses of groundwater samples from 1,472 Seymour Aquifer wells are on record in the database. For the purpose of statistical evaluation and mapping, only the most recent sampling event for a given parameter was chosen for each well. The most recent data were used in order to assess the current status of the quality of groundwater in the Seymour Aquifer.

4.8.3 Results

The following sections discuss the results of the water-quality analysis conducted for groundwater in the Seymour Aquifer. A comparison of the chemistry of the groundwater in the aquifer to drinking water standards is provided in the first section and the quality of groundwater in the Seymour Aquifer for irrigation purposes is provided in the second section. A comparison of groundwater quality in the Seymour Aquifer to drinking water and irrigation standards considering only the most recent chemical analysis for each constituent is provided in Table 4.8.1.

4.8.3.1 Drinking Water Quality

Screening levels for drinking water supply are based on the maximum contaminant levels established in the Texas Administrative Code (Title 30 Chapter 290). Primary maximum contaminant levels are legally enforceable standards that apply to public water systems to protect human health from contaminants in drinking water. Secondary maximum contaminant levels are non-enforceable guidelines for drinking water contaminants that may cause aesthetic effects (taste, color, odor, foaming), cosmetic effects (skin or tooth discoloration), and technical effects (e.g., corrosivity, expensive water treatment, plumbing fixture staining, scaling, and sediment).

High levels of nitrate are common in the Seymour Aquifer, with the concentration in 69 percent of the sampled wells exceeding the primary maximum contaminant level of 10 milligrams per liter. Figure 4.8.1 shows that nitrate concentrations exceed the primary maximum contaminant level throughout the extent of the aquifer. High concentrations of nitrate can cause serious illness in infants younger than 6 months old. These high nitrate levels may be due in part to domestic sewage contamination, the use of nitrate fertilizers on croplands, or leaching from soil following conversion of former grasslands and mesquite groves to cropland, coupled with the shallow and permeable nature of the Seymour Aquifer (Price, 1979). Measurements of nitrate concentrations at multiple times are plotted, along with the screening level (i.e., the primary maximum contaminant level), for several wells in Figure 4.8.2. These plots indicate that concentrations have varied significantly over time at some locations and have remained fairly stable at other locations. At all but one of the selected locations, the nitrate concentration exceeded the screening level at some point in time. The nitrate concentration in well 21-26-711 located in Knox County has significantly exceeded the screening level in all samples.

Fluoride is a naturally occurring element found in most rocks. At very low concentrations, fluoride is a beneficial nutrient. At a concentration of 1 milligram per liter, fluoride helps to prevent dental cavities. However, at concentrations above the secondary maximum contaminant level of 2 milligrams per liter, fluoride can stain children's teeth. Approximately 14 percent of the sampled wells have exceeded this level. At concentrations above the primary maximum contaminant level of 4 milligrams per liter, fluoride can cause a type of bone disease. About 1.5 percent of the sampled wells have exceeded this level. Fluoride concentrations in groundwater in the Seymour Aquifer relative to these two screening levels are shown in Figure 4.8.3.

Total dissolved solids, a measure of water salinity, is the sum of concentrations of all dissolved ions (such as sodium, calcium, magnesium, potassium, chloride, sulfate, carbonates) plus silica. Some dissolved solids, such as calcium, give water a pleasant taste, but most make water taste salty, bitter, or metallic. Dissolved solids can also increase the corrosiveness of water. Total dissolved solids have exceeded the Texas secondary maximum contaminant level of 1,000 milligrams per liter in approximately 40 percent of the sampled wells (Figure 4.8.4). Time series of total dissolved solids concentrations for several wells, along with the screening level of 1,000 milligrams per liter, are shown in Figure 4.8.5. The concentration temporarily exceeded the screening level in the 1970 to 1990 time frame in well 21-28-711 located in Knox County and in the 1990s in well 21-41-407 located in Haskell County.

Concentrations of sulfate, a major component of total dissolved solids, have exceeded the secondary maximum contaminant level of 300 milligrams per liter in 14 percent of the sampled wells. Concentrations of chloride, another major component of total dissolved solids, have exceeded the secondary maximum contaminant level of 300 milligrams per liter in 24 percent of the sampled wells (Figure 4.8.6). Time series plots of chloride concentrations for several wells, along with the screening level of 300 milligrams per liter, are shown in Figure 4.8.7. Also included on these plots are chloride to sulfate ratios. This ratio is useful for identifying contamination from oil field brines which have a very high chloride content relative to their sulfate content (R.W. Harden and Associates, 1978). A large spike in chloride concentration occurred in several of the wells. For wells with data to calculate the chloride to sulfate ratio, the spike in chloride concentration is accompanied by a spike in the chloride to sulfate ratio, indicating possible contamination by oil field brines. The chloride to sulfate ratio in groundwater in the Seymour Aquifer is plotted in Figure 4.8.8. A ratio of greater than 1 can be an indication of contamination by oil field brines.

In summary, the utility of water from the Seymour Aquifer as a drinking water supply is limited in some areas for health reasons, primarily due to elevated nitrate concentrations and for taste reasons due to saltiness.

4.8.3.2 Irrigation Water Quality

The utility of groundwater from the Seymour Aquifer for crop irrigation was evaluated based on its salinity hazard, sodium hazard, and concentrations of chloride. The results of this evaluation are presented below.

Saline irrigation waters limit the ability of plants to take up water from soils. Various crops differ in their tolerance of high salinity. Salinity is often measured by the total dissolved solids content or electrical conductivity of the water. The salinity hazard classification system of the United States Salinity Laboratory (1954) indicates that waters with an electrical conductivity over 750 micromhos present a high salinity hazard, and those with electrical conductivity over 2250 micromhos present a very high salinity hazard. Of the sampled Seymour Aquifer wells, 95 percent have exhibited a high salinity hazard and 25 percent have exhibited a very high salinity hazard (Figure 4.8.9).

Irrigation water containing large amounts of sodium causes a breakdown in the physical structure of soil such that movement of water and air through the soil is restricted. A sodium hazard condition generally results when the sodium concentration in water is in excess of 60 percent of total cations and is widely measured in terms of sodium adsorption ratio (United States Salinity Laboratory, 1954):

$$\text{Sodium Adsorption Ratio} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}} \qquad (4.8.1)$$

where the sodium (Na), calcium (Ca), and magnesium (Mg) concentrations are expressed in milliequivalents per liter. Waters with a sodium absorption ratio above 18 are considered to present a high sodium hazard, generally considered unsuitable for continuous use for irrigation. Waters with a sodium absorption ratio above 26 are considered to represent a very high sodium hazard. Less than 1 percent of the sampled Seymour Aquifer wells exhibit a high sodium hazard and none exhibit a very high sodium hazard (Figure 4.8.10).

Most crops cannot tolerate chloride levels above 1,000 milligrams per liter for an extended period of time (Tanji, 1990). This level has been exceeded in about 2.4 percent of sampled Seymour Aquifer wells (see Figure 4.8.6).

Table 4.8.1 Occurrence and levels of some commonly measured groundwater quality constituents in the Haskell-Knox-Baylor pod of the Seymour Aquifer.

Constituent	Type of Standard	Screening Level	Number of Results	Number of Results Exceeding Screening Level	Percentage of Results Exceeding Screening Level
Fluoride	primary maximum contaminant level[1]	4 mg/L	1,030	15	1.5%
Nitrate	primary maximum contaminant level[1]	10 mg/L	1,123	780	69%
Chloride	secondary maximum contaminant level[1]	300 mg/L	1,326	324	24%
Fluoride	secondary maximum contaminant level[1]	2 mg/L	1,030	145	14%
Sulfate	secondary maximum contaminant level[1]	300 mg/L	1,180	160	14%
Total Dissolved Solids	secondary maximum contaminant level[1]	1,000 mg/L	977	388	40%
Specific Conductance	Irrigation Salinity Hazard - High[2]	750 µmhos/cm	1,056	1,003	95%
Specific Conductance	Irrigation Salinity Hazard - Very High[2]	2,250 µmhos/cm	1,056	261	25%
Sodium Absorption Ratio	Irrigation Sodium Hazard -High[2]	18	970	3	0.3%
Sodium Adsorption Ratio	Irrigation Sodium Hazard - Very High[2]	26	970	0	0%
Chloride	Irrigation Hazard[3]	1,000 mg/L	1,326	32	2.4%

[1] 30 Texas Administrative Code, Chapter 290, Subchapter F

[2] United States Salinity Laboratory (1954)

[3] Tanji (1990)

mg/L = milligrams per liter
µmhos/cm = micromhos per centimeter
% = percent

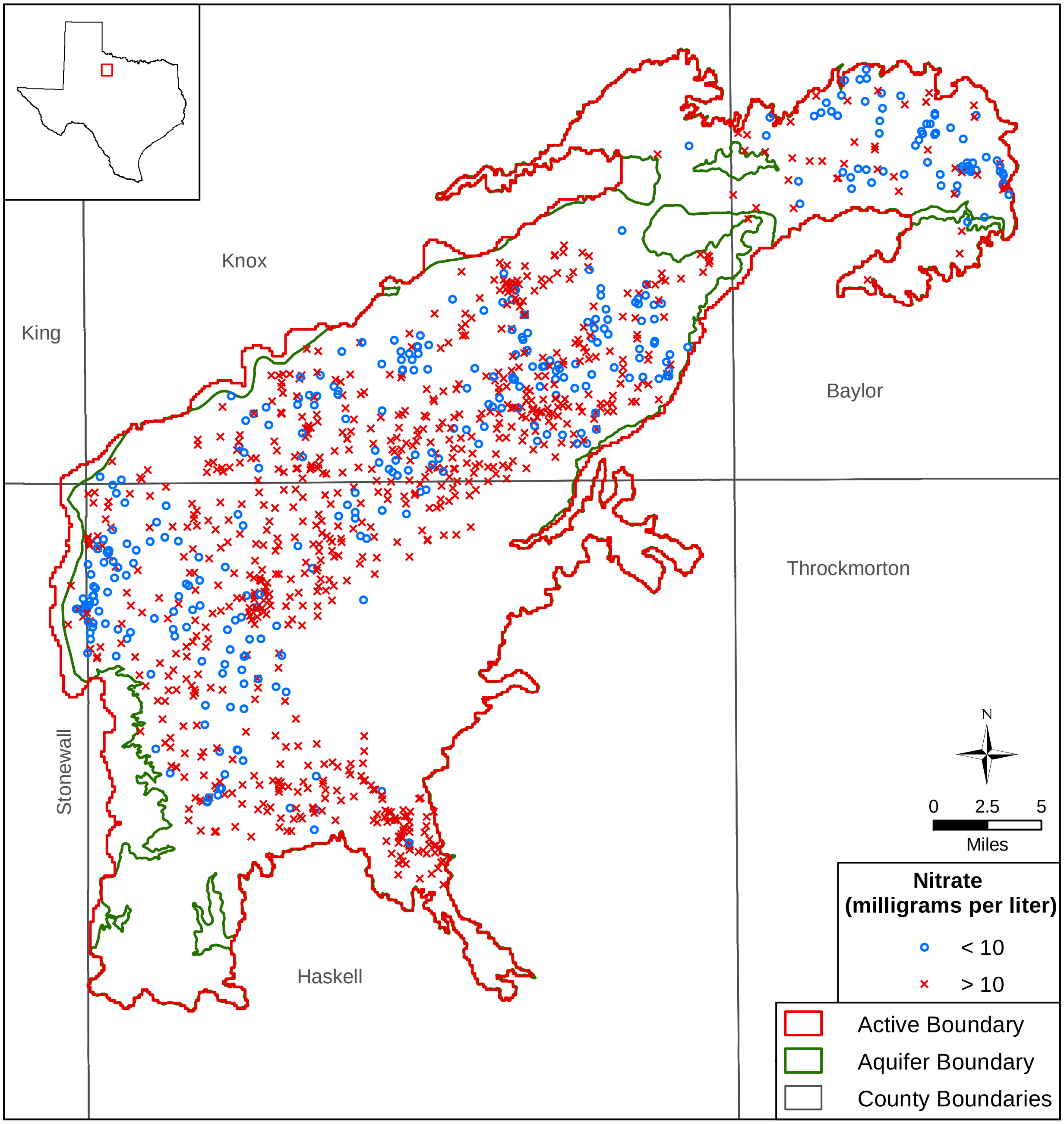


Figure 4.8.1 **Nitrate concentrations in the groundwater in the Seymour Aquifer.**

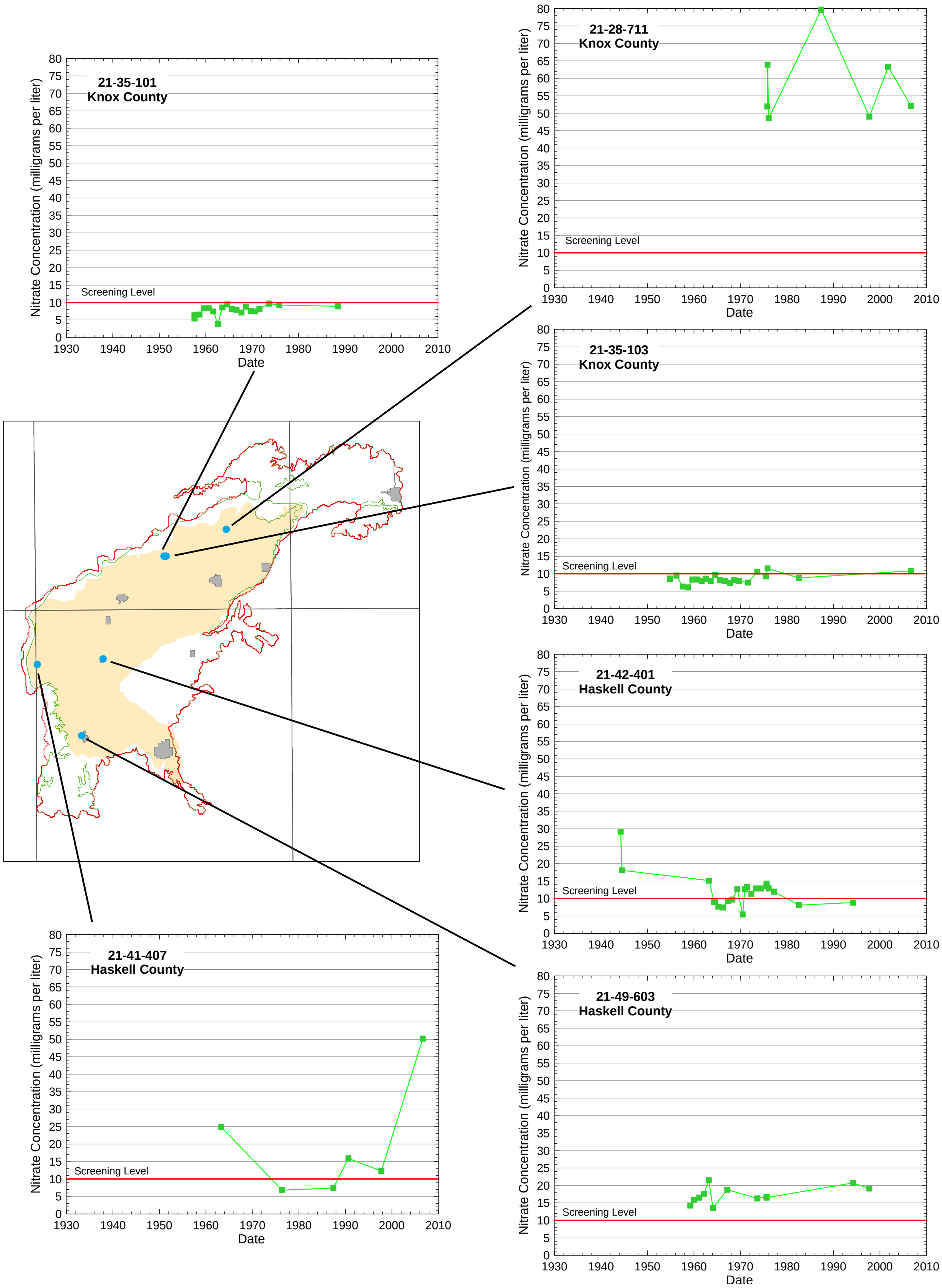


Figure 4.8.2 Time series of nitrate concentrations in the Seymour Aquifer at selected wells.

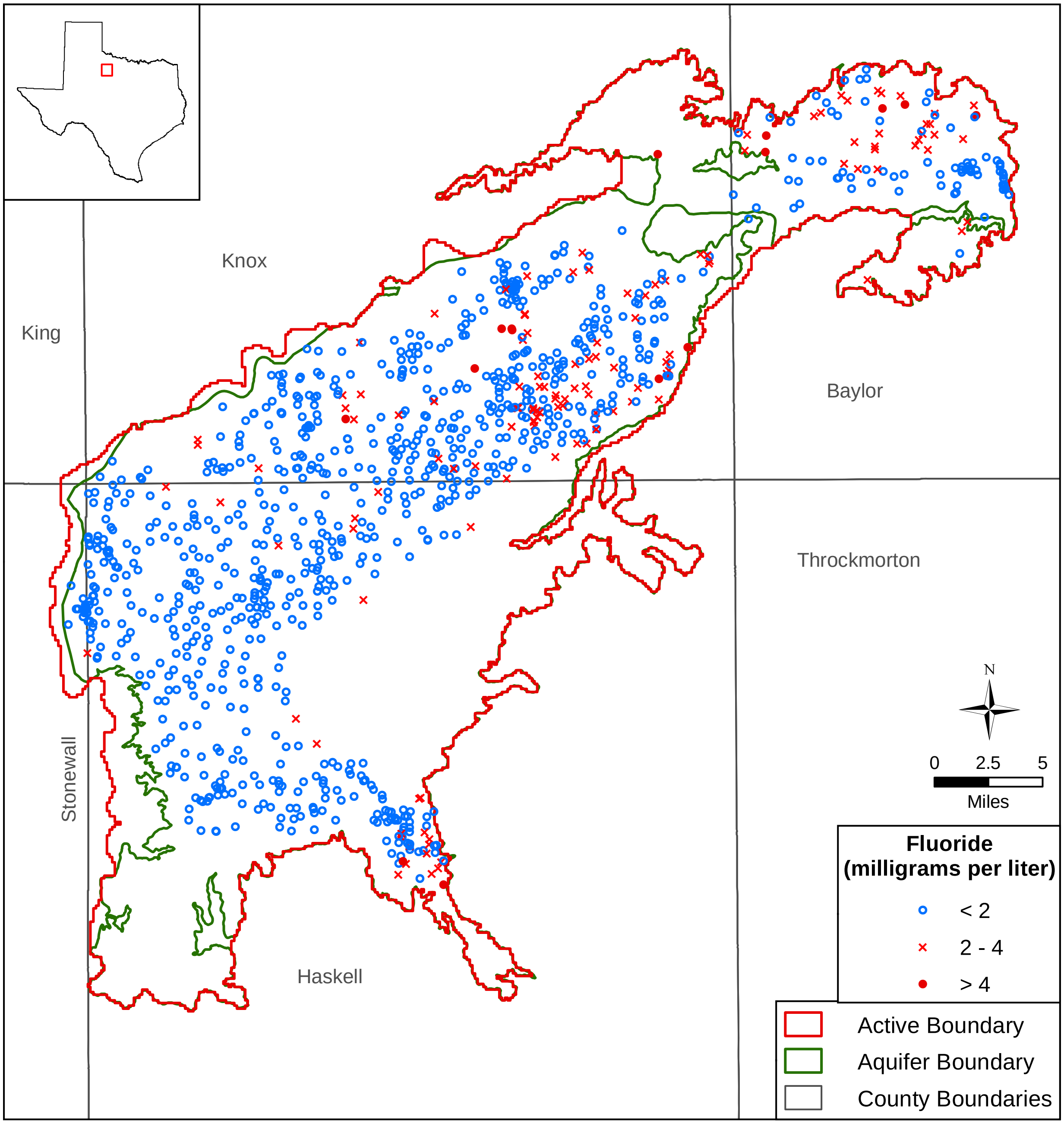


Figure 4.8.3 Fluoride concentrations in the Seymour Aquifer.

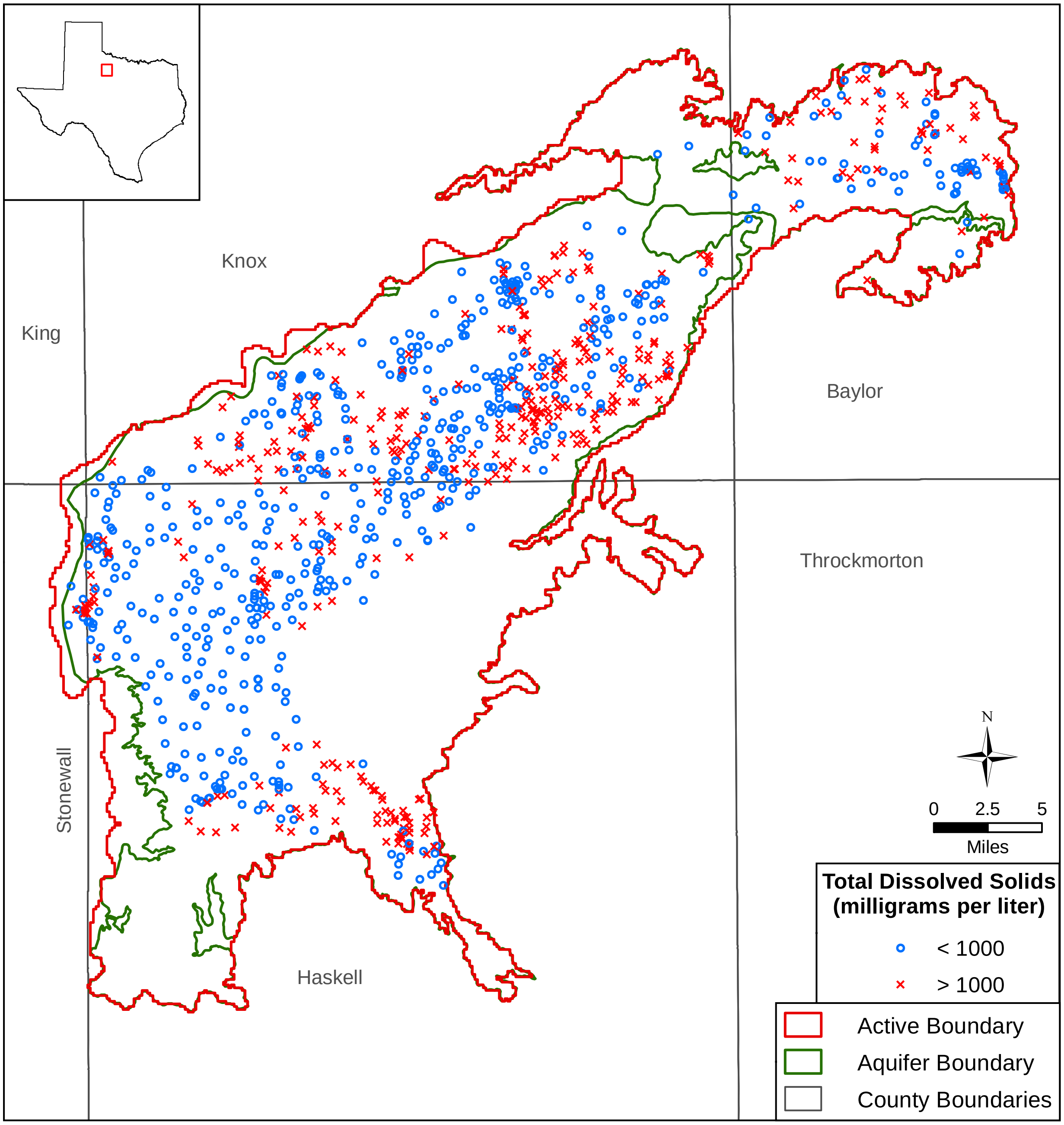


Figure 4.8.4 **Total dissolved solids concentrations in the Seymour Aquifer.**

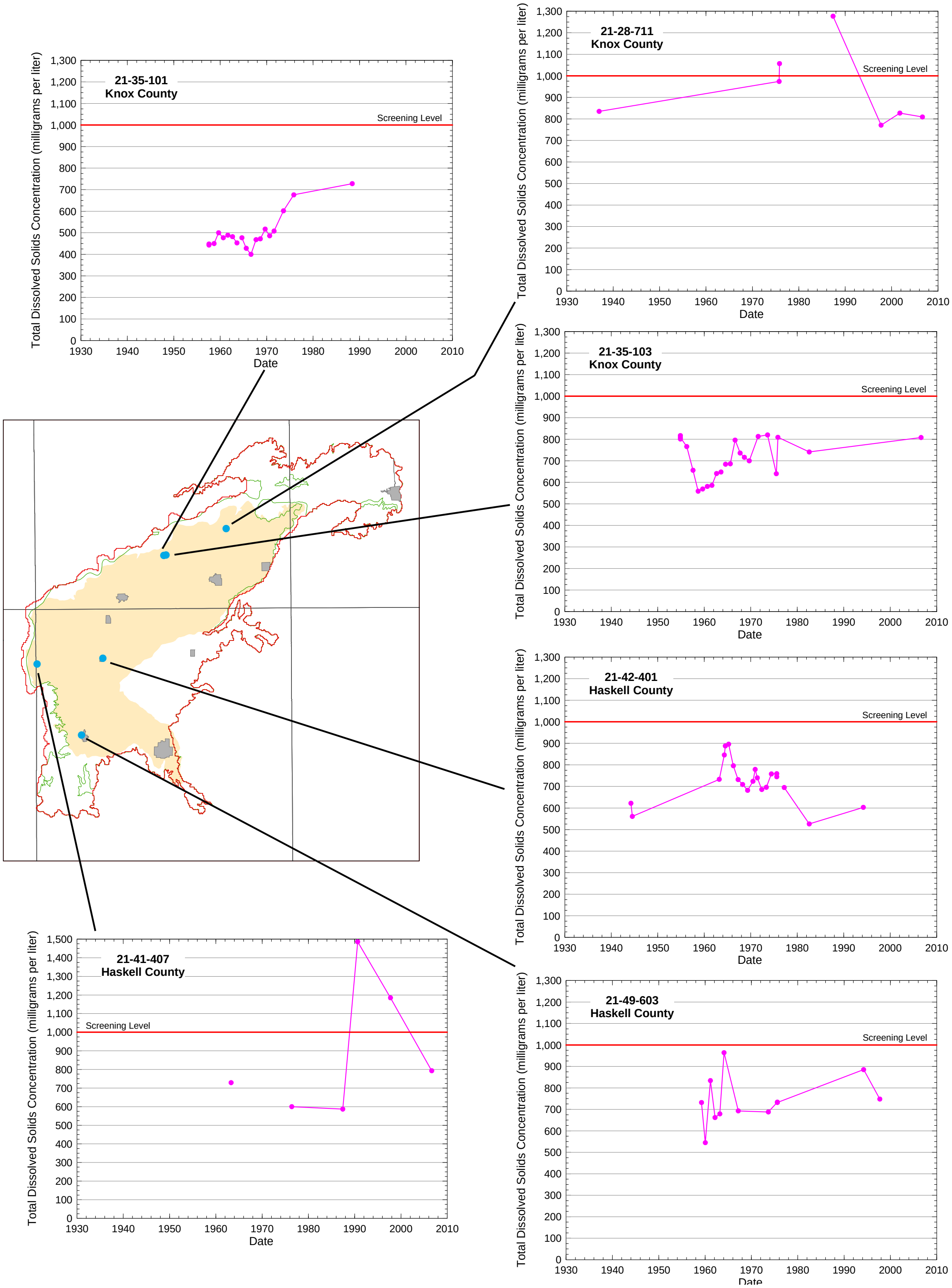


Figure 4.8.5 Time series of total dissolved solids concentrations in the Seymour Aquifer for selected wells.

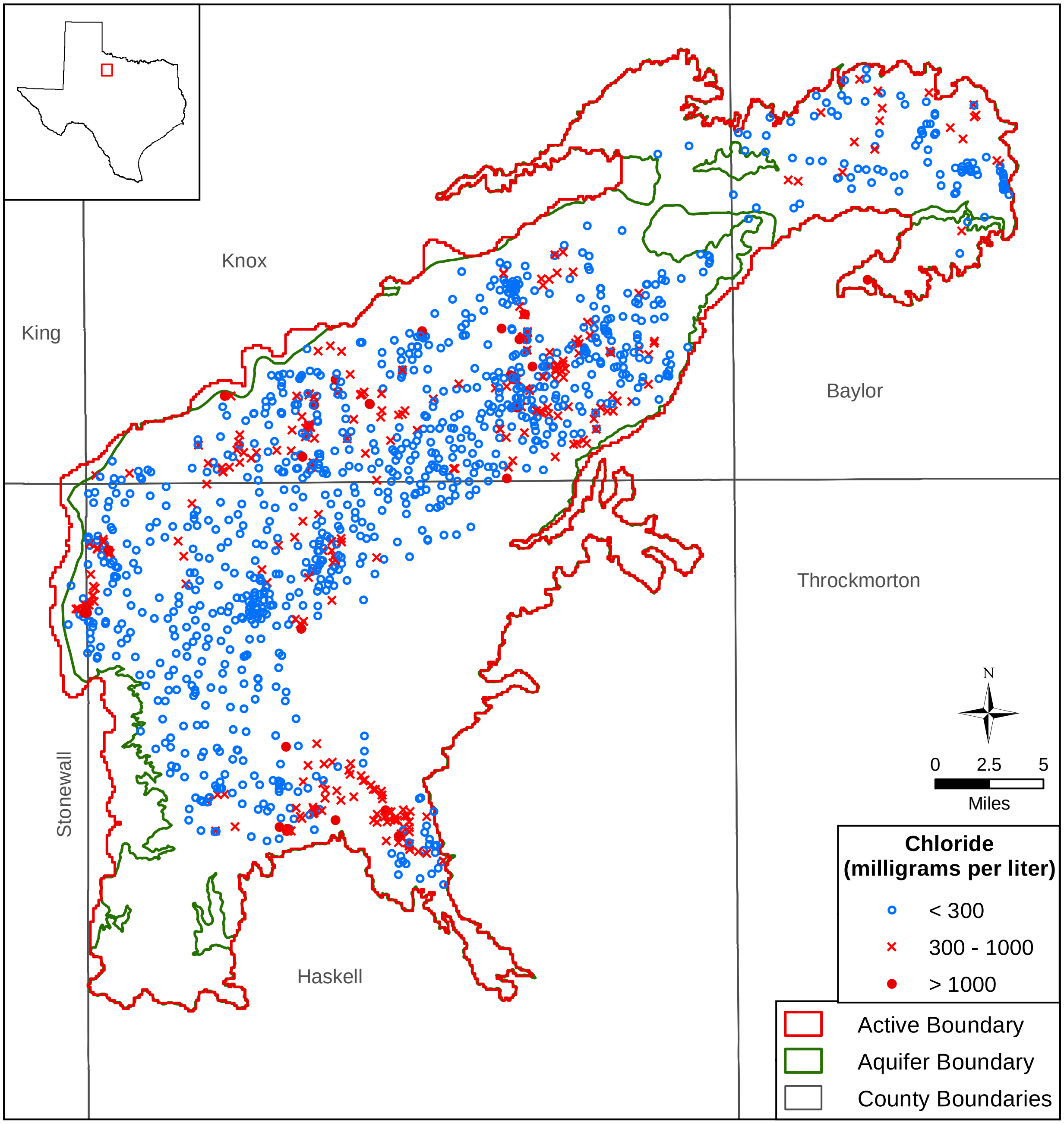


Figure 4.8.6 **Chloride concentrations in the Seymour Aquifer.**

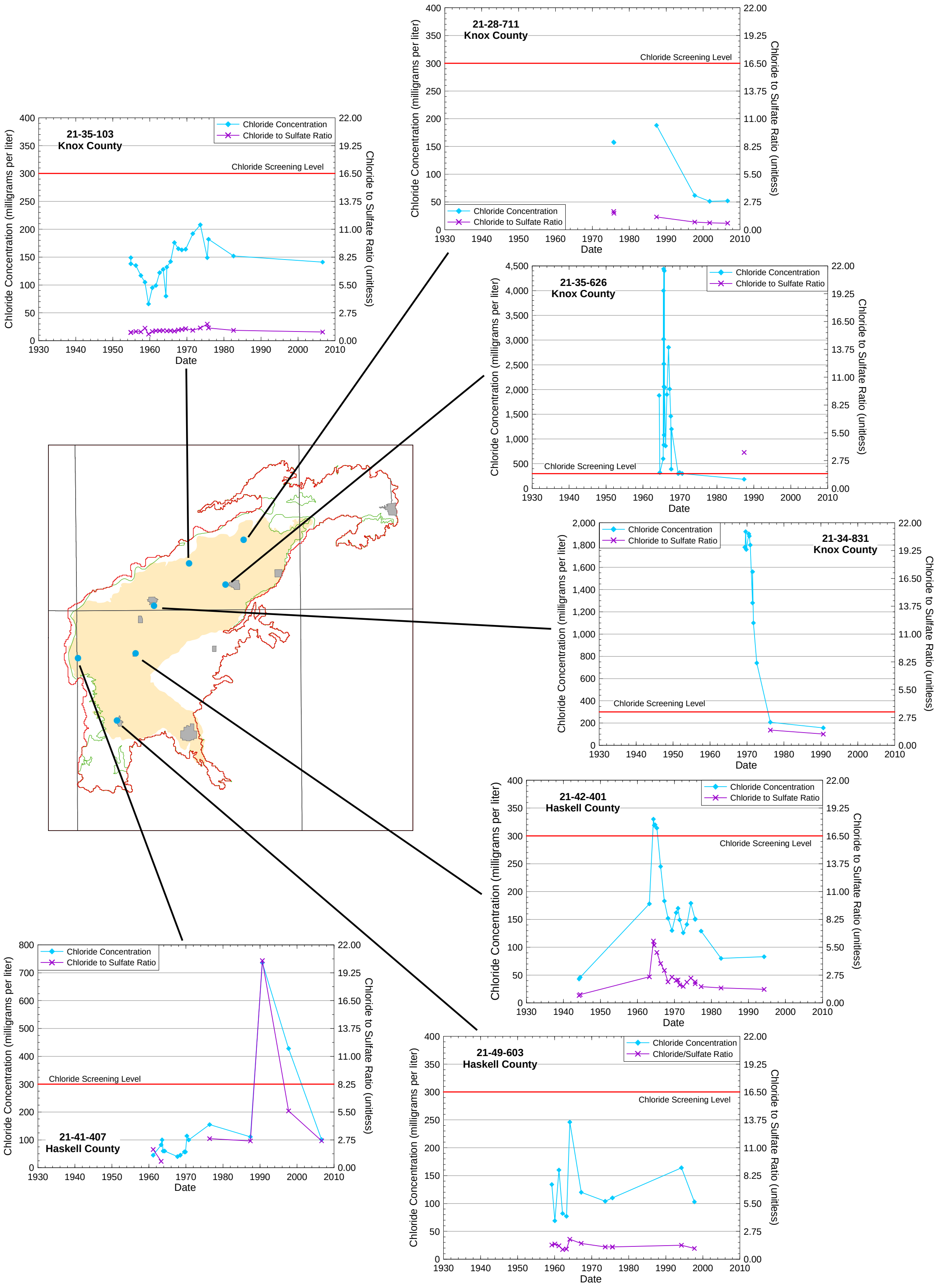


Figure 4.8.7 Time series of chloride concentration and chloride/sulfate ratio for selected wells.

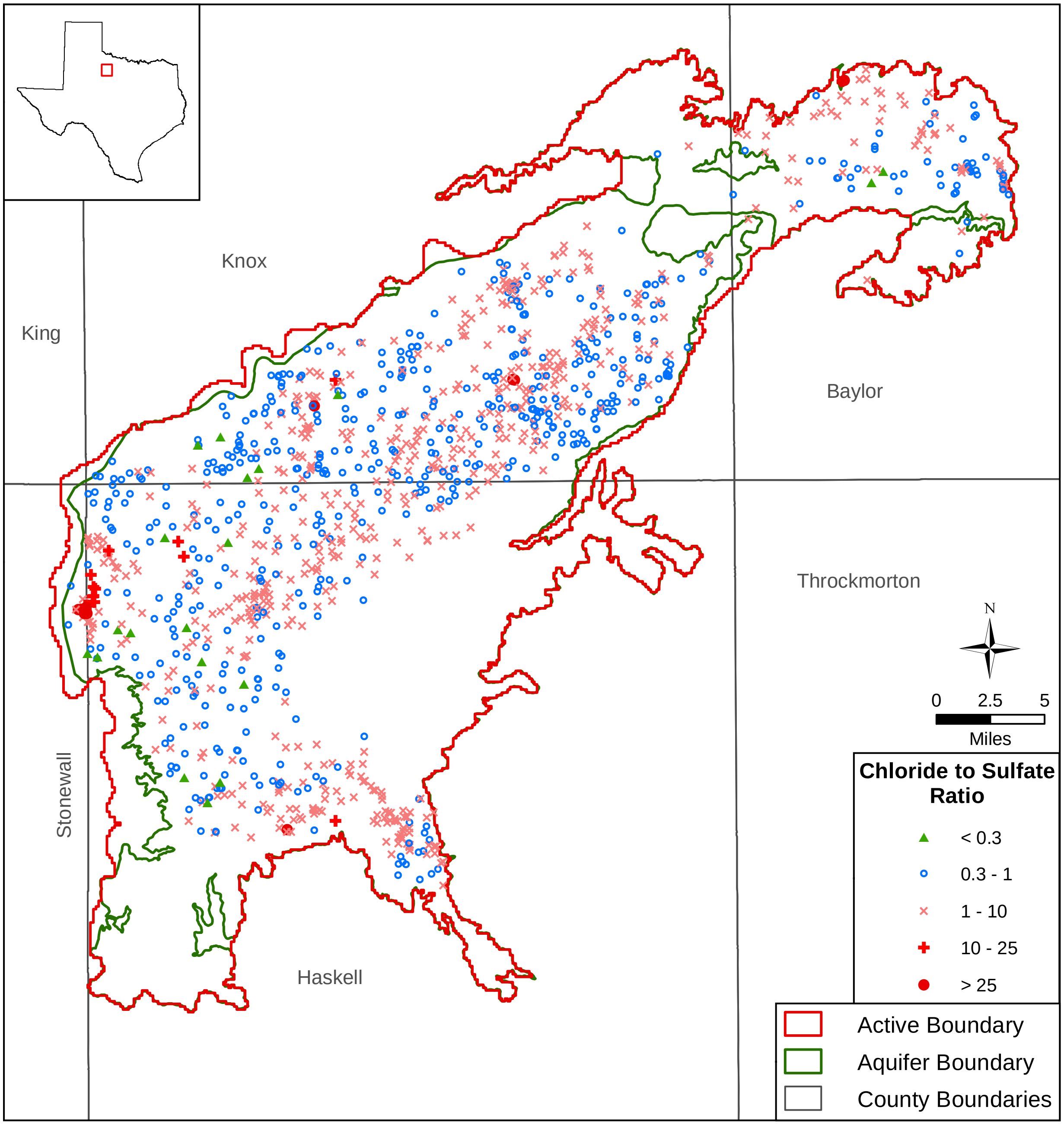


Figure 4.8.8 Chloride to sulfate ratios in the Seymour Aquifer.

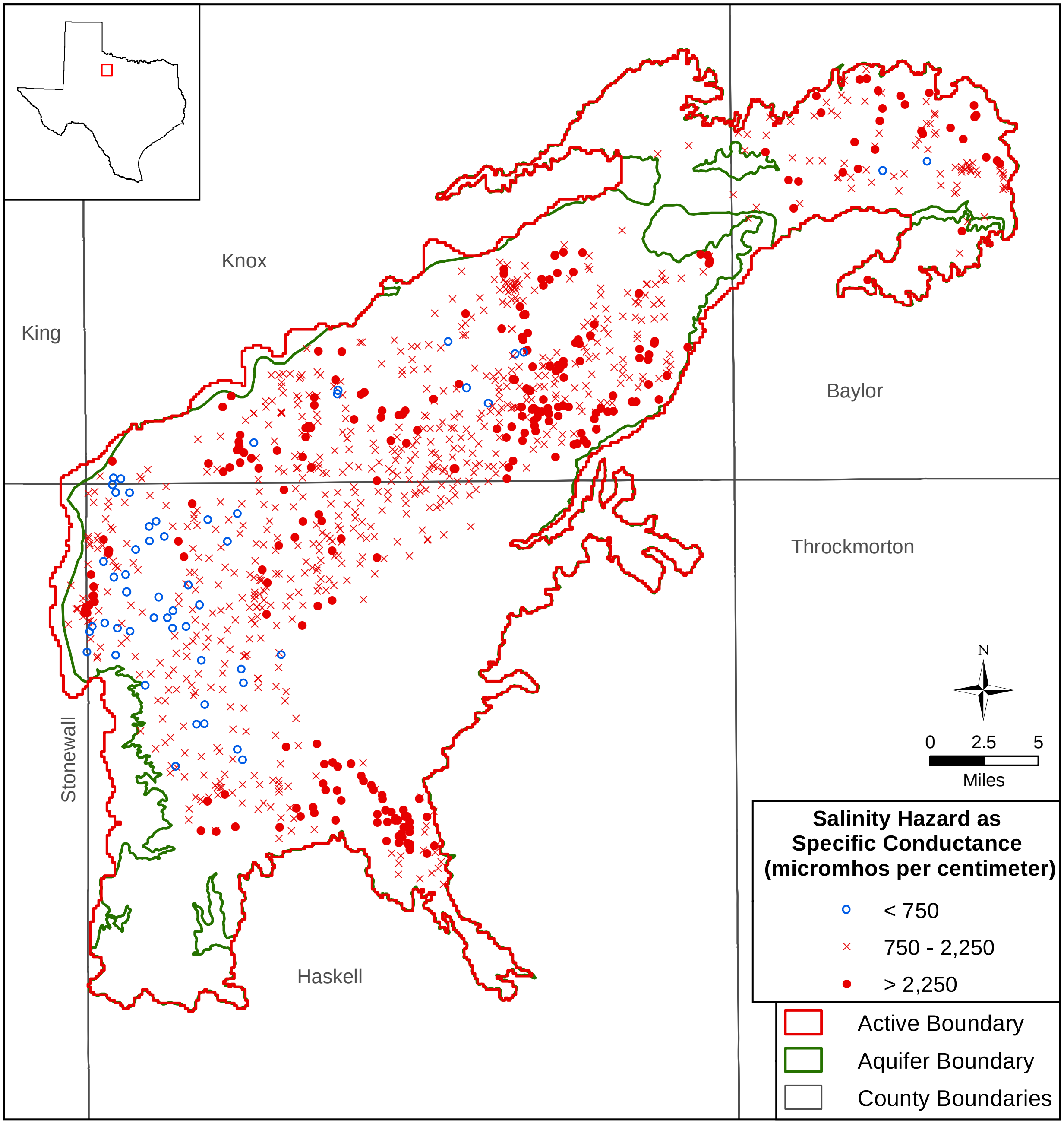


Figure 4.8.9 **Salinity hazard of groundwater in the Seymour Aquifer.**

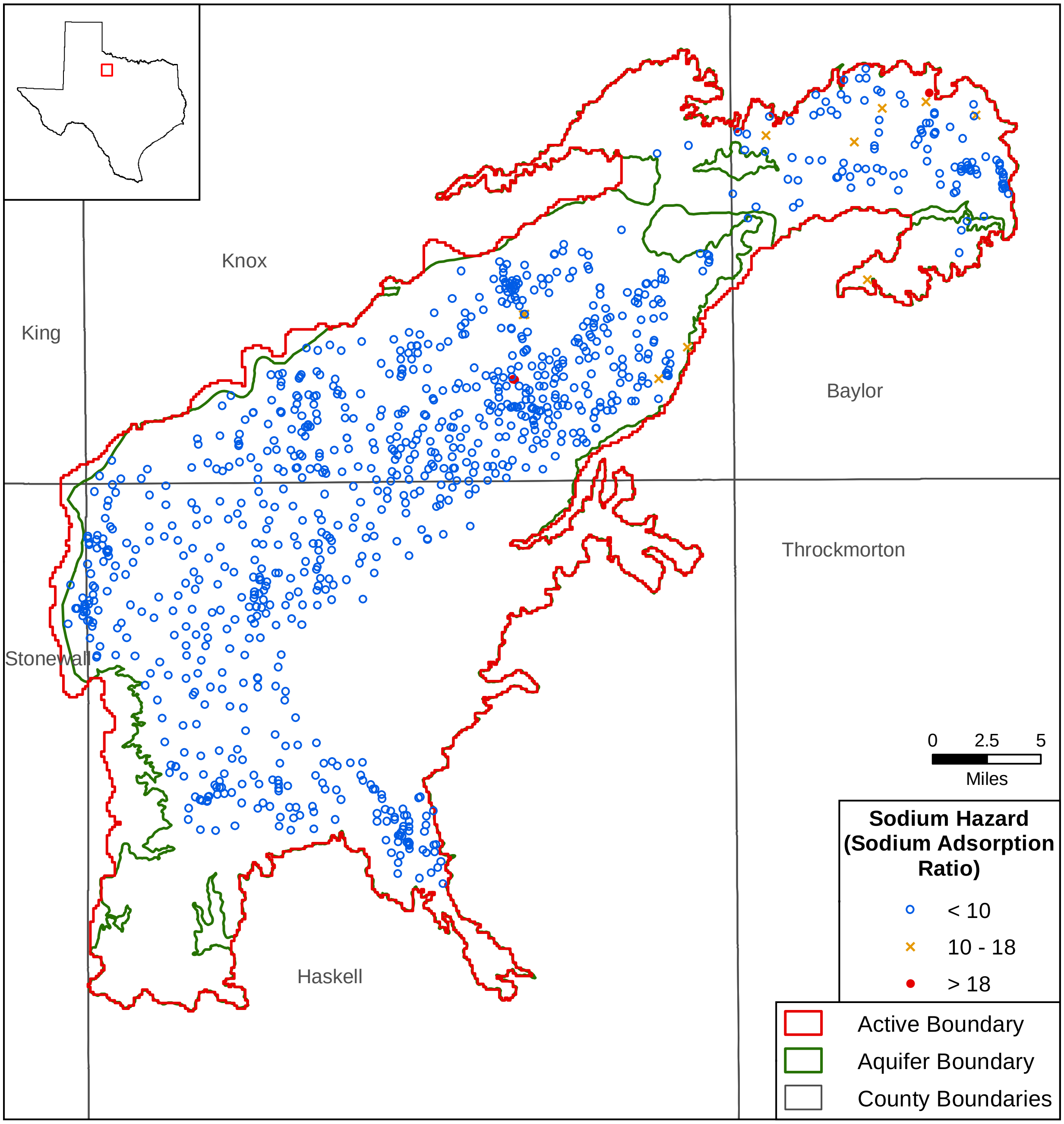


Figure 4.8.10 Sodium hazard (sodium adsorption ratio) of groundwater in the Seymour Aquifer.

5.0 Conceptual Model of Groundwater Flow for the refined Seymour Aquifer Groundwater Availability Model

The conceptual model for groundwater flow in the Haskell-Knox-Baylor pod of the Seymour Aquifer is based on the hydrogeologic setting, described in Section 4.0. The conceptual model is a simplified representation of the hydrogeologic features which govern groundwater flow in the aquifer. These include the hydrostratigraphy, hydraulic properties, hydraulic boundaries, recharge and natural discharge, and anthropogenic stresses from land use changes and pumping. Each element of the conceptual model is described below. The schematic diagram in Figure 5.0.1 depicts a simplified, cross-section conceptualization of the hydrogeologic model describing inflow to and outflow from the Haskell-Knox-Baylor pod of the Seymour Aquifer.

The conceptual model for the refined groundwater availability model for the Haskell-Knox-Baylor pod of the Seymour Aquifer includes two layers. The upper layer represents the Seymour Aquifer and the lower layer represents the upper portion of the Permian-age sediments that underlie and are in hydrologic communication with the Seymour Aquifer. The Seymour Aquifer is the most productive groundwater zone in the model. The Permian-age sediments locally supply small quantities of saline water. The upper portion of the Permian-age sediments is included in the model to allow for cross-formational flow between the Seymour Aquifer and the Permian-age formations and to allow for groundwater flow from the Seymour Aquifer through the Permian-age formations to the Brazos River along the western edge of the Seymour Aquifer in Haskell and Knox counties. In addition to identifying the hydrostratigraphic layers of the groundwater system, the conceptual model defines the mechanisms of recharge and discharge, historical changes in recharge and discharge and their effect on the aquifer, and groundwater flow through the aquifer.

Recharge is a complex function of precipitation, soil type, geology, land cover, water level and soil moisture, topography, and evapotranspiration. Precipitation, land cover, evapotranspiration, water-table elevation, and soil moisture vary spatially and temporally, whereas soil type, geology, and topography vary spatially. Precipitation that falls on the land surface is lost by runoff to streams and rivers and evapotranspiration, which leaves only a small fraction of the precipitation to recharge the aquifer.

Diffuse recharge occurs preferentially in topographically higher interstream areas. Focused recharge along streams can occur when the water table in the aquifer is below the stream-level elevation. If stream levels are lower than surrounding groundwater levels, groundwater discharges to streams resulting in gaining streams. Direct precipitation is the dominate recharge mechanism occurring in the Seymour aquifer. There is some very small potential for focused recharge from the Brazos River only in Baylor County. This focused recharge is expected to be periodic and occur predominantly during flood events.

Under undisturbed conditions, groundwater recharge is balanced by natural groundwater discharge. For a typical aquifer, undisturbed conditions coincide with the time period prior to pumping. For the Seymour aquifer, however, undisturbed conditions were disrupted by land use changes many years prior to the advent of significant pumping. The Seymour Formation and alluvial sediments that make up the Seymour Aquifer have experienced several land use changes as described in Section 2.3. Those changes and the resulting conceptualization of the aquifer are discussed below.

The original condition of the land overlying the Seymour Aquifer was that of native grassland or savannah plant communities prior to any disturbance by Anglos (Texas Parks and Wildlife, 2007). This land coverage was in existence until about 1880 when all nomadic Indians and buffalo were driven off the land (Texas State Historical Association, 2008). During this time, aquifer recharge and natural aquifer discharge would have been balanced. The condition of the Seymour Aquifer under these conditions is unknown. Although the native grasses would have required significant water, it is likely that some precipitation infiltrated to the groundwater and recharged the aquifer resulting in some saturated thickness. This assumption is supported by the existence of historical springs flowing from the aquifer (see Section 4.5.2). This time period is considered to be the only time period in recent history when the Seymour Aquifer was at true steady-state conditions.

The introduction of the first Anglo residents to the three counties in about 1880 brought with it livestock (Texas State Historical Association, 2008), which resulted in a significant change in the land coverage. Livestock were allowed to overgraze the land, which resulted in a depletion of the native grasses and the expansion of phreatophytes, particularly mesquite (Texas Parks and

Wildlife, 2007). It is very likely that evapotranspiration from the water table significantly increased when the land coverage changed from grassland or savannah plant communities to more brushland or woodland habitats due to overgrazing of the land. In addition, the damaged surface soil from overgrazing results in higher runoff and, consequently, lower infiltration of precipitation. These increases in evapotranspiration and runoff may have resulted in an increase in natural aquifer discharge and a decrease in aquifer recharge resulting in an overall decrease in water in storage in the aquifer. Early records indicate that little to no water was available over large portions of the Seymour Aquifer in Haskell and Knox counties in about 1905/1906 (Gordon, 1913).

The land use once again changed in the early 1900s when agricultural activity significantly increased in the three counties. The Texas State Historical Association (2008) indicates that farming was beginning to dominate ranching in the area in about 1910. The surge in farming continued, with a short lull following World War I, until about 1930 and was a result largely of the cotton boom from about 1900 to 1910 and then again from about 1920 to 1930. The advent of farming brought the clearing and plowing of land for crops. In addition, terracing of the land began in about 1928 (Sherrill, 1965). Replacing some of the brushland and woodland habitats with crops resulted in a reduction in water-table evapotranspiration. This, plus loosening the soil with plows, the presence of bare soil between crops, and the collection of rainfall with terraces, caused in an increase in aquifer recharge. This increase in recharge and decrease in natural aquifer discharge created an imbalance that resulted in increased water in storage in the aquifer. Bandy (1934) found that many portions of the Seymour Formation in Haskell County began filling with groundwater between the early 1900s and 1934 resulting in rising water levels and the development of water-logged areas. The existence of water-logged areas indicates that aquifer recharge exceeded natural aquifer discharge in these areas. In addition, groundwater was found in areas of the aquifer that were dry in the early 1900s as reported by Gordon (1913).

The 1930s were economically hard on these three counties due to the Great Depression and the Dust Bowl (Texas State Historical Association, 2008). It is likely that some of the land previously planted with crops was left uncultivated during the 1930s. Ogilbee and Osborne (1962) estimate an end to the rise in water levels in the Seymour Formation in about 1940.

Information regarding land use and aquifer conditions during the 1940s could not be found in the literature.

Although a general history of land use for the Seymour Aquifer from about 1910 to about 1940 was found, there is very little water-level data for the aquifer during this period (see Figure 4.3.2). Therefore, the amount of water in the aquifer and the location of the water table are unknown. One well located near the city of Rochester in Haskell County shows a rise in water level of 31 feet between 1926 and 1944. These observed water levels support the theory that the Seymour Aquifer experienced a significant rise in water level in some areas of Haskell County between about 1900 and 1934. Several wells in Haskell and Knox counties have an early water level measurement from 1936, 1937, or 1944 and then measurements at later times. For these wells, there is not a consistent trend in water level. Therefore, there are not enough data to support the hypothesis that the Seymour Aquifer experienced maximum water levels in about 1940.

Haskell, Knox, and Baylor counties, along with much of the state of Texas, experienced a severe drought from about 1951 through about 1957. The use of groundwater for irrigation purposes also exploded during this time. Ogilbee and Osborne (1962) state that there were 25 irrigation wells in Haskell and Knox counties in 1951 and 1,100 in 1956. In response to the drought and increased pumpage for irrigation purposes, water levels in the Seymour Aquifer generally fell during the 1950s. Since the late 1950s, water levels in the Seymour Aquifer have fluctuated due to changes in precipitation and pumping but have, in general, remained relatively stable (i.e., no significant permanent drawdown and no significant, permanent gains in storage). Table 5.0.1 summarizes conditions in the Seymour Aquifer over time.

Water removed from an aquifer by pumping is supplied through decreased groundwater storage (i.e., decreased water levels), reduced groundwater discharge, and sometimes increased aquifer recharge. If pumping stays relatively constant, a new steady-state condition will be established. In this new equilibrium, the source of pumped water will be drawn completely from either reduced discharge or increased recharge, with the latter component usually being relatively small. Bredehoeft (2002) terms these two volumes as capture. He also defines sustainable yield (pumped flow rate that is sustainable) as being equal to the rate of capture. For a given production volume to be sustainable (i.e., groundwater levels reach a new steady state), there must be enough groundwater capture volume to balance the pumping volume. If pumping exceeds the potential available capture volume for a basin, that basin will experience water-level declines until there are no recoverable groundwater reserves. This is equivalent to the "unstable" basin concept discussed in Freeze (1971).

The sources of capture as a result of pumping the Seymour Aquifer are expected to be primarily from capture of aquifer discharge with little to no potential for capture of additional recharge. Because the majority of the Brazos River in the active model area lies at an elevation beneath the Seymour Aquifer, little increased recharge potential from the river can be expected as a result of pumping. However, additional capture through reduced stream discharge is likely. Lowering the water table, as a result of pumping, beneath the extinction depth of phreatophyte and crop root systems may lead to discharge capture through the reduction of groundwater evapotranspiration. The distribution of rooting depths throughout the Seymour Aquifer is not well characterized and difficult to define, however. Additional capture through reduced flow to springs and seeps is also likely.

The conceptual model of the Seymour Aquifer since about 1957 is that of a stable groundwater aquifer where historical groundwater pumping values can be satisfied by groundwater capture over long-time periods (i.e., decades). Groundwater from the Seymour Aquifer is predominately used for irrigation purposes. Consequently, the aquifer is doubly stressed during periods of low precipitation because recharge is low and pumpage is high. Therefore, declines in water levels are observed for periods of little rainfall, but then the aquifer recovers during periods of abundant rainfall. However, when averaged since about 1957, water levels in the Seymour Aquifer have been fairly stable. The potential for capture of additional recharge as a result of pumping the Seymour Aquifer is expected to be low because the areas of high recharge (i.e., sandy soils in topographic highs) are generally distant from areas of natural discharge (i.e., topographic lows at the edge of the formation.

Groundwater from the Seymour Aquifer discharges to springs and seeps, local creeks, and the Brazos River, predominately in Baylor County. Springs and seeps occur along much of the boundary of the Seymour Aquifer. Some discharge from the Seymour Aquifer occurs by cross-formational flow to the underlying Permian-age sediments. Although the rates of cross-formational flow are expected to be low, when aggregated over the entire aquifer, they may amount to a significant portion of the Seymour Aquifer water budget. A large fraction of natural discharge is anticipated to be evapotranspiration, due to the shallow nature of the water table and the existence of phreatophytes throughout portions of the aquifer (R.W. Harden and Associates, 1978). This is expected to be especially important where the water table is shallowest and phreatophyte density is highest.

Groundwater flow within the Seymour Aquifer is controlled by topography, structure, and permeability variations. A map showing the inferred groundwater flow pattern is shown in Figure 4.3.4. This figure shows a major recharge area in the topographically high, sand hills region in the southwestern portion of the aquifer. Groundwater flow generally follows the topographical gradient along the major axis of the aquifer and discharges laterally to springs and seeps and the Brazos River and Lake Creek.

The boundaries for the refined groundwater availability model for the Haskell-Knox-Baylor pod of the Seymour Aquifer are represented conceptually in Figure 5.0.1. The boundary beneath the Seymour Aquifer is the erosion surface of the Permian-age sediments through which some groundwater discharges.

The vast majority of the inflow into the Seymour Aquifer occurs through recharge from precipitation. Recharge under pre-development conditions is expected to be lower than that estimated for modern conditions.   A much lesser amount of inflow may occur from cross-formational flow from the Clear Fork Group, with only minimal inflows possible from losing streams into the alluvium of the Seymour Aquifer. Significant avenues for outflow include baseflow into streams and cross-formational discharge to the Clear Fork Group. Evapotranspiration and spring discharge together are expected to constitute a significant amount of outflow in riparian areas, from the edges of the Seymour aquifer, and from areas with dense phreatophyte growth. Under modern transient conditions, pumping is expected to be the largest discharge mechanism.

Table 5.0.1 Summary of conditions in the Seymour Aquifer.

Time Period	Description	Condition of Aquifer
prior to 1880	undisturbed; aquifer recharge equal to natural aquifer discharge	unknown, but some saturated thickness as indicated by flow in historical springs
1880-1900	increasing natural aquifer discharge through evapotranspiration due to replacement of native grassland and savannahs with brushlands and woodlands and decreased infiltration of precipitation due to damaged surface soil; natural aquifer discharge exceeds aquifer recharge	groundwater found in some areas but not in others; portions of aquifer dry
1900-1940	increasing aquifer recharge and decreased natural aquifer discharge due to development of agriculture; aquifer recharge exceeds natural aquifer discharge	aquifer fills with water, water-logged conditions in some areas
1940-1950	unknown	unknown
1950-1957	significant increase in pumping, for irrigation purposes; drawdown of groundwater over large portions of the aquifer; elimination of water-logged areas; aquifer discharge through pumping exceeds aquifer recharge	declining water levels
1957-1997	aquifer recharge about equal to aquifer discharge (natural and via pumping) over long time periods (i.e., decades)	stable groundwater aquifer with long-term water level fluctuations a function of precipitation and pumping

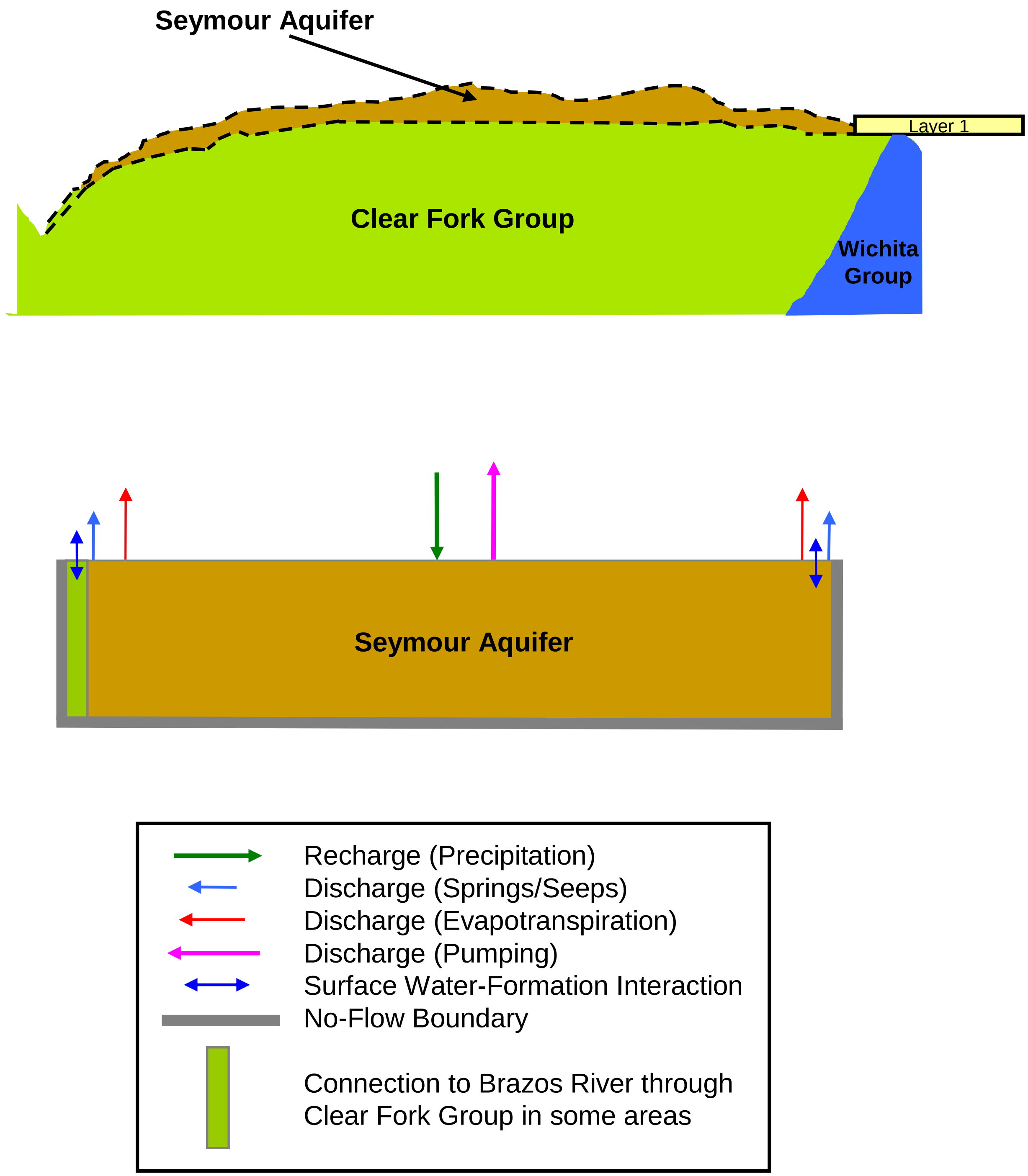


Figure 5.0.1 **Conceptual groundwater flow model (cross-sectional view) for the refined groundwater availability model for the Haskell-Knox-Baylor pod of the Seymour Aquifer.**

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APPENDIX A

Results of Investigation of Likely Completion of UNKNOWN wells located in the Seymour Aquifer

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Appendix A Results of Investigation of Likely Completion of UNKNOWN wells located in the Seymour Aquifer

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2122813	Baylor	UNKNOWN	112SYMR	NA	Seymour Aquifer well because Preston (1978) states it produced 230 gallons per minute in 1969
2122910	Baylor	UNKNOWN	112SYMR	NA	Seymour Aquifer spring because Preston (1978) states it flows from Permian sandstone but source is Seymour alluvium
2129320	Baylor	UNKNOWN	112SYMR	NA	no information; not used
2129409	Baylor	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2130214	Baylor	UNKNOWN	112SYMR	NA	Seymour Aquifer spring because Preston (1978) states it flowed 25 gallons per minute in 1969 and owner reports it has never stopped flowing and Preston (1978) lists the Seymour Formation as the water bearing unit
2130801	Baylor	UNKNOWN	112SYMR	NA	not located in the pod
2141710	Haskell	110ALVM	112SCFX	S,P	Seymour Aquifer well (5)
2133704	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133717	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133719	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133720	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133801	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133915	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133916	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134704	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134710	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134730	Haskell	UNKNOWN	112SYMR	NA	no information; not used
2134827	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134851	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134926	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134946	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2135719	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135722	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135723	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135724	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135729	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135732	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135820	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135835	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141103	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141106	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141108	Haskell	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2141110	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141116	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141117	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141119	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141120	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141121	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141122	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141124	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141126	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141128	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141129	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141130	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141131	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2141132	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2141133	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141134	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141135	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141136	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141138	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141141	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141201	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141205	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141206	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141207	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141208	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141209	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141306	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141309	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141312	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141313	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141315	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141316	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141320	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141322	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141323	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141403	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141408	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141409	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141412	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2141414	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141415	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141418	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141424	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141428	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141501	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141506	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141507	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141508	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141509	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141513	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141514	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141601	Haskell	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2141602	Haskell	110ALVM	112SYMR	P	Seymour Aquifer well (5)
2141603	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141604	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141605	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141607	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141608	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141609	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141611	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141612	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141613	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141614	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141616	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2141620	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141701	Haskell	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2141704	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141709	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141804	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141806	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141812	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141816	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141817	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141905	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141906	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141907	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141909	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141911	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141914	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141916	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142106	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142108	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142109	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142112	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142114	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142117	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142130	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142131	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142204	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2142216	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142218	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142222	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142227	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142228	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142229	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142255	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142257	Haskell	UNKNOWN	112SYMR	NA	no information; not used
2142305	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142331	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142334	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142335	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142336	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142340	Haskell	UNKNOWN	112SYMR	NA	no information; not used
2142414	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142416	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142420	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142421	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142423	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142424	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142425	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142426	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142427	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142437	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142442	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2142452	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142453	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142503	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142507	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142508	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142509	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142510	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142511	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142513	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142514	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142515	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142516	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142517	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142518	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142602	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142603	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142705	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142706	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142707	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142712	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142803	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2143108	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2143109	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2143110	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2143202	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2143203	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149204	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149205	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149209	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149302	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149303	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149304	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149305	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149307	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149308	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2149313	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2149314	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2149403	Haskell	UNKNOWN	112SYMR	P	Permian well (7)
2149403	Haskell	UNKNOWN	112SYMR	P	Permian well (9)
2149505	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2149903	Haskell	112SYMR	112SYMR	S,P	Seymour Aquifer well (5)
2149906	Haskell	112SYMR	112SYMR	S,P	Seymour Aquifer well (5)
2149908	Haskell	112SYMR	112SYMR	S,P	Seymour Aquifer well (5)
2150104	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150106	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150107	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150108	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150109	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150111	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150112	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2150206	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150301	Haskell	112SYMR	112SYMR	P	Permian well (7)
2150302	Haskell	112SYMR	112SYMR	P	Seymour Aquifer well (5)
2150415	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150443	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150506	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150512	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150514	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150515	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150530	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150531	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150555	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150556	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150557	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150558	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150559	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150639	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2150651	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150652	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150654	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150703	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2150804	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151407	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151411	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151413	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2151418	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151420	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151421	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151714	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151715	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151717	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2151723	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151725	Haskell	110ALVM	112SYMR	P	Seymour Aquifer well (5)
2151729	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151730	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151733	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151735	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151737	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151738	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2151739	Haskell	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2142901	Haskell	310PRMN	310PRMN	P	Permian well (3)
2151301	Haskell	310PRMN	310PRMN	P	Permian well (3)
2136702	Haskell	318CLFK	318CLFK	P	Permian well (3)
2141706	Haskell	318CLFK	318CLFK	P	Permian well (3)
2143901	Haskell	318CLFK	318CLFK	P	Permian well (3)
2143902	Haskell	318CLFK	318CLFK	P	Permian well (3)
2144201	Haskell	318CLFK	318CLFK	P	Permian well (3)
2144202	Haskell	318CLFK	318CLFK	P	Permian well (3)
2144203	Haskell	318CLFK	318CLFK	P	Permian well (3)
2144501	Haskell	318CLFK	318CLFK	P	Permian well (3)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2144601	Haskell	318CLFK	318CLFK	P	Permian well (3)
2144701	Haskell	318CLFK	318CLFK	P	Permian well (3)
2144801	Haskell	318CLFK	318CLFK	P	Permian well (3)
2149622	Haskell	318CLFK	318CLFK	P	Permian well (3)
2149801	Haskell	318CLFK	318CLFK	P	Permian well (3)
2149901	Haskell	318CLFK	318CLFK	P	Permian well (3)
2149902	Haskell	318CLFK	318CLFK	P	Permian well (3)
2149905	Haskell	318CLFK	318CLFK	P	Permian well (3)
2150803	Haskell	318CLFK	318CLFK	P	Permian well (3)
2150811	Haskell	318CLFK	318CLFK	P	Permian well (3)
2150903	Haskell	318CLFK	318CLFK	P	Permian spring (4)
2151601	Haskell	318CLFK	318CLFK	P	Permian well (3)
2151901	Haskell	318CLFK	318CLFK	P	Permian well (3)
2152101	Haskell	318CLFK	318CLFK	P	Permian well (3)
2152402	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157201	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157202	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157301	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157302	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157303	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157401	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157701	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157801	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157802	Haskell	318CLFK	318CLFK	P	Permian well (3)
2157901	Haskell	318CLFK	318CLFK	P	Permian well (3)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2157902	Haskell	318CLFK	318CLFK	P	Permian well (3)
2158101	Haskell	318CLFK	318CLFK	P	Permian well (3)
2158102	Haskell	318CLFK	318CLFK	P	Permian well (3)
2158301	Haskell	318CLFK	318CLFK	P	Permian well (3)
2158302	Haskell	318CLFK	318CLFK	P	Permian well (3)
2158501	Haskell	318CLFK	318CLFK	P	Permian well (3)
2158601	Haskell	318CLFK	318CLFK	P	Permian well (3)
2159201	Haskell	318CLFK	318CLFK	P	Permian well (3)
2159202	Haskell	318CLFK	318CLFK	P	Permian well (3)
2159601	Haskell	318CLFK	318CLFK	P	Permian well (3)
2159602	Haskell	318CLFK	318CLFK	P	Permian well (3)
2159603	Haskell	318CLFK	318CLFK	P	Permian well (3)
2159801	Haskell	318CLFK	318CLFK	P	Permian well (3)
2159901	Haskell	318CLFK	318CLFK	P	Permian well (3)
2133710	Knox	100ALVM	100ALVM	S,P	Seymour Aquifer well (5)
2133807	Knox	110ALVM	112SCFX	S,P	Seymour Aquifer well (5)
2133809	Knox	110ALVM	112SCFX	S,P	Seymour Aquifer well (5)
2119101	Knox	UNKNOWN	112SYMR	NA	not located in the pod
2119213	Knox	UNKNOWN	112SYMR	NA	not located in the pod
2119215	Knox	UNKNOWN	112SYMR	NA	not located in the pod
2119317	Knox	UNKNOWN	112SYMR	NA	not located in the pod
2119318	Knox	UNKNOWN	112SYMR	NA	not located in the pod
2119322	Knox	UNKNOWN	112SYMR	NA	not located in the pod
2127808	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2127810	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2127901	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2127907	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2127912	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2127915	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2127918	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2127919	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2127921	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2127922	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2127942	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128302	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128406	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128408	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128409	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128503	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128601	Knox	UNKNOWN	112SYMR	P	Permian spring (8)
2128601	Knox	UNKNOWN	112SYMR	P	Permian spring based on the water bearing unit identified as the Permian in R.W. Harden and Associations (1978)
2128602	Knox	UNKNOWN	112SYMR	P	Permian spring (8)
2128602	Knox	UNKNOWN	112SYMR	P	Permian spring based on the water bearing unit identified as the Permian in R.W. Harden and Associations (1978)
2128702	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128706	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128707	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128708	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128712	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128714	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2128716	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128721	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128722	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128804	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128806	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128807	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128810	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128812	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128819	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128820	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128824	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128826	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128827	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128828	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128833	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128904	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128905	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128908	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128909	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2128910	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2129408	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2129702	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133601	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133607	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133611	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2133705	Knox	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2133711	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2133806	Knox	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2133808	Knox	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2133811	Knox	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2133908	Knox	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2134208	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134225	Knox	UNKNOWN	112SYMR	NA	no information; not used
2134226	Knox	UNKNOWN	112SYMR	NA	no information; not used
2134303	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134313	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134314	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134317	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134318	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134322	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134323	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2134326	Knox	UNKNOWN	112SYMR	NA	no information; not used
2134406	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134428	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134434	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134443	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134445	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2134446	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134508	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134510	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2134517	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134520	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134521	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134524	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134525	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134526	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134533	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134536	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134549	Knox	UNKNOWN	112SYMR	NA	no information; not used
2134607	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134611	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134617	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134621	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134622	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134626	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134646	Knox	UNKNOWN	112SYMR	NA	no information; not used
2134705	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134712	Knox	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2134713	Knox	110ALVM	112SYMR	S,P	Permian well (7)
2134716	Knox	110ALVM	112SYMR	S,P	Seymour Aquifer spring (6)
2134721	Knox	110ALVM	112SYMR	S,P	Seymour Aquifer well (5)
2134724	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134806	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134807	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134828	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2134836	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134846	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134847	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2134920	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135105	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2135106	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2135127	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135128	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135130	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135136	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135137	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135138	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135139	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135140	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135142	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135143	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135214	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135218	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135219	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135316	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135319	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135322	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135323	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135324	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135339	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

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State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2135340	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135342	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135343	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135344	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135345	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135346	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135347	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135348	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135349	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135350	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135351	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135353	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135354	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135355	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135356	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135357	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135358	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135359	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135360	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135363	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135365	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135366	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135368	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135420	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135433	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2135445	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135447	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135458	Knox	UNKNOWN	112SYMR	NA	no information; not used
2135506	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135517	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135540	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135541	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135542	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135610	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135615	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135616	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135623	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135625	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135626	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135627	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135629	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135631	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135632	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135633	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135634	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135635	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135636	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135637	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135639	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135640	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2135645	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135646	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135647	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135649	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135656	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135657	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135668	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135708	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135709	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135710	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135802	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135812	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135828	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135831	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2135901	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136106	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136108	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136117	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136126	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136128	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136129	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136130	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136135	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136136	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136137	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2136138	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136139	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136140	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136141	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136142	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136143	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136144	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136147	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136148	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136149	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136150	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136151	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136152	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136212	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136213	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136215	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136217	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136218	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136219	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136221	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136223	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136233	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136234	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136235	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136236	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2136237	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136238	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136239	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136240	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136241	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136305	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136316	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136318	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136409	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136411	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136412	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136414	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136416	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136418	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136421	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136422	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136423	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136424	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136425	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136433	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136434	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136437	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136439	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136446	Knox	UNKNOWN	112SYMR	NA	no information; not used
2136507	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2136511	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136601	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2136602	Knox	UNKNOWN	112SYMR	S	Seymour Aquifer spring (2)
2127301	Knox	310PRMN	310PRMN	P	Permian well (3)
2126101	Knox	318CLFK	318CLFK	P	Permian well (3)
2126301	Knox	318CLFK	318CLFK	P	Permian well (3)
2126302	Knox	318CLFK	318CLFK	P	Permian well (3)
2126303	Knox	318CLFK	318CLFK	P	Permian well (3)
2126304	Knox	318CLFK	318CLFK	P	Permian well (3)
2126402	Knox	318CLFK	318CLFK	P	Permian well (3)
2126502	Knox	318CLFK	318CLFK	P	Permian well (3)
2126503	Knox	318CLFK	318CLFK	P	Permian well (3)
2126504	Knox	318CLFK	318CLFK	P	Permian well (3)
2126601	Knox	318CLFK	318CLFK	P	Permian well (3)
2126701	Knox	318CLFK	318CLFK	P	Permian well (3)
2127101	Knox	318CLFK	318CLFK	P	Permian well (3)
2127102	Knox	318CLFK	318CLFK	P	Permian well (3)
2127103	Knox	318CLFK	318CLFK	P	Permian well (3)
2128101	Knox	318CLFK	318CLFK	P	Permian well (3)
2128201	Knox	318CLFK	318CLFK	P	Permian well (3)
2133201	Knox	318CLFK	318CLFK	P	Permian well (3)
2133401	Knox	318CLFK	318CLFK	P	Permian well (3)
2133501	Knox	NOT_APPL	NOT_APPL	P	Permian well (9)
2141405	Stonewall	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141420	Stonewall	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)

Appendix A, continued

State Well Number	County	Aquifer Code Assigned in August 2008	Previous Aquifer Code	Water Bearing Unit in R.W. Harden and Associates (1978)	Comments
2141422	Stonewall	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141425	Stonewall	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141427	Stonewall	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2141705	Stonewall	UNKNOWN	112SYMR	S	Seymour Aquifer well (1)
2248601	Stonewall	UNKNOWN	112SYMR	S,P	Seymour Aquifer well (5)

NA - not included in R.W. Harden and Associations (1978)
P - water bearing unit identified as Permian by R.W. Harden and Associates (1978)
S - water bearing unit identified as Seymour by R.W. Harden and Associates (1978)
(1) considered to be a Seymour Aquifer well based on the water bearing unit identified as the Seymour Formation in R.W. Harden and Associates (1978)
(2) considered to be a Seymour Aquifer spring based on the water bearing unit identified as the Seymour Formation in R.W. Harden and Associates (1978)
(3) considered to be a Permian well based on aquifer code
(4) considered to be a Permian spring based on aquifer code
(5) considered to be a Seymour Aquifer well based on water chemistry
(6) considered to be a Seymour Aquifer spring based on water chemistry
(7) considered to be a Permian well based on water chemistry
(8) considered to be a Permian spring based on water chemistry
(9) considered to be a Permian well based on water bearing unit identified as Permian in R.W. Harden and Associates (1978) and location outside of the Seymour Aquifer

APPENDIX B

Draft Conceptual Model Report Comments and Responses

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Seymour Conceptual Report to the Texas Water Development Board

REQUIRED CHANGES

Conceptual Report Comments:

General Comments:

General:

In general the report is very well written and thoroughly addresses the requirements for the development of the conceptual model

When referencing the Texas Water Development Board in the text, please either universally abbreviate to “TWDB” or spell out as “Texas Water Development Board.” The text currently contains a mixture of these reference styles.

Completed.

In the final report we suggest adding a comparison table or section to indicate differences and similarities between this refined portion and the original Seymour Groundwater Availability Model, as well as implications for anyone using the original model results for one of the other pods.

No change. A table of this type should be included in the model report rather than the conceptual model report.

Specific Comments:

Introduction.

1. Page 1-3, last paragraph, last sentence. Please use a different term other than “intersects” such as overlaps, or overlays, or falls within.

   Completed. See Section 1.0 last paragraph.

Chapter 2.

2. Figure 2.0.6, Page 2-8, per Exhibit B, Attachment 1 page 19 of 24 of contract please include the date of the Groundwater Conservation District map on the Figure.

   Completed. See Figure 2.0.6 title.

3. Sect. 2.0, Pg. 2-1, Para. 2: The last sentence references that depth of lower model boundary will be determined based on model behavior. Please explain what behavior(s) and how the behavior(s) will determine the lower model boundary.

   Completed. Statement removed from text.

4. Sect. 2.0, Pg. 2-2, Para. 1: Please use a different term other than “intersects” such as is contained within or lies within.

   Completed. See Section 2.0, last paragraph.

5. Figure 2.0.5, page 2-7, Please rename “Regional Water Planning Group” to Regional Water Planning Area. Please check GIS Regional Water Planning Area boundary files and make certain they are correct since they do not appear to coincide with county boundaries.

   Completed. See Figure 2.0.5. County boundaries updated using TWDB county shapefile dated 8-12-08.

6. Figure 2.0.6, page 2-8, Please check GIS Groundwater Conservation District boundary files and make certain they are correct since they do not appear to coincide with county boundaries.

   Completed. See Figure 2.0.6. County boundaries updated using TWDB county shapefile dated 8-12-08.

7. Sect. 2.1, Pg. 2-13, Para. 2: The first sentence references Texas Parks and Wildlife, 2009 which is not in the references section. Figure 2.1.2 references Texas Parks and Wildlife, 2006 for ecological regions. Please add or correct as needed.

   Completed. See Figure 2.1.2 and Reference Section.

8. Sect. 2.0, Pg. 2-14, Para. 2: Please correct grammar for last sentence and remove “average”.

   Completed. Removed sentence, see Section 2.1, paragraph 5.

9. Sect. 2.0, Pg. 2-14, Para. 3: Last sentence states a high of 27 inches per year in the east whereas Figure 2.1.9 shows 27.5 inches per year in the east.

   Completed. See Section 2.1, paragraph 6.

10. Physiography and climate section 2.1, per Exhibit B, Attachment 1 page 2 of 24 of contract please include some discussion of evapotranspiration in the study area.

    Completed. See Section 2.1, last paragraph and Figure 2.1.12.

11. Sect. 2.1, Pg. 2-14, Para. 2: Please reference Texas A&M University (2002) in the text as the source of the mean annual temperature information.

    Completed. See Section 2.1, paragraph 5.

12. Sect. 2.1, Pg. 2-14, Para. 3: The text states that 12 precipitation gages are in the study area while Figure 2.17 shows 13. Please correct text or figure as needed. Also, please reference National Climate Data Center (2001) in the text as the source of precipitation gage data.

    Completed. See Section 2.1, paragraph 6.

13. Figure 2.1.9, page 2-24, Please use a monochromatic color scale for ratio data types.

    Completed. See Figure 2.1.9.

14. Figure 2.2.1, page 2-31, Structural syncline shows blue boundary. Please label blue edge of syncline with anticline symbol if it is indeed an anticline as most synclines are adjacent to anticlines.

    No change. There is an anticline to the north of this feature outside of the study area but not one to the south of the feature per the original source (i.e., Price, 1979).

15. Figure 2.2.2, page 2-32, Please list rock units for legend with youngest on top and oldest on bottom.

    Complete. See Figure 2.2.2.

16. Figure 2.2.3, page 2-33, Please revise schematic of generalized stratigraphy so that stratigraphic units correlate with geochronologic units or correct figure such that the Seymour does not appear to be of Permian age.

    Completed. See Figure 2.2.3

Chapter 4.

17. Section 4.0, please consider moving the five paragraph discussion of change in aquifer codes to Section 4.3 Water Levels and Regional Groundwater Flow.

    No change. Since the discussion of changes in aquifer code includes a discussion of springs, which are addressed in Section 4.5, as well as wells no change was made.

18. Sect. 4.0, Pg. 4-2, Para. 1: Though I think the inclusion of the 455 wells in R.W. Harden and Associates is important, the logic behind their use described here could be clearer. Suggest adding that it is unlikely that these wells in the study area were drilled past the

relatively high quality water of the Seymour Aquifer into the lower quality water of the Permian units.

Completed. See Section 4.0, paragraph 3.

19. Sect. 4.0, Pg. 4-3, Para. 3: This paragraph references Figure 4.0.1, which is not included at the end of this section. Suggest moving Figure 4.0.1 to this section instead of sect. 4.1.

    Completed. See end of Section 4.0.

20. Please provide more detailed discussion regarding the resolution used to interpolate the structural surfaces.

    Completed. See Section 4.2, paragraph 4.

21. Please provide a more detailed discussion of the hydrostratigraphy of the Clear Fork Group formations.

    Completed. See Section 4.1, paragraph 4.

22. Section 4.1 It's not clear why the active area extends past the aquifer boundary mostly on the western side of the aquifer. Please explain.

    Completed. See Section 4.1, last paragraph.

23. Sect. 4.1, Pg. 4-5, Para. 2: This paragraph references "volcanic ash" as a constituent of the Seymour Aquifer. Nowhere else is this mentioned within the report. Please check for accuracy of this statement or be consistent throughout the report when discussing sediment composition of the Seymour Aquifer.

    Completed. See Section 2.2, paragraph 5, Section 4.1, paragraph 2, and Section 4.6, first paragraph.

24. Sect. 4.1, There is no detailed discussion of the formations within the Clear Fork Group. Please provide more discussion of the formations within the Clear Fork Group regarding lithology, hydraulic characteristics of the Choza, Vale, and Arroya formations.

    Completed. See Section 4.1, paragraph 4.

25. Sect. 4.2, Pg. 4-9, Para. 3: The report states that "These values [Avg. value of contour surface at 1 mile grid scale] were then merged with the other point data." Was this merge an average of the contour value with zero or more drillers logs or was a different method used? Please clarify how the merge took place.

    Completed. See Section 4.2, paragraph 3.

26. Sect. 4.2, Pg. 4-15, Fig. 4.2.4: The text on page 4-10 states that a minimum thickness of 20 feet was assumed for the structure. However, Fig. 4.2.4 shows many areas with a thickness of less than 20 feet. Please revise text and/or figure as needed.

    Completed. See Figure 4.2.4.

27. Sect. 4.2, Pg. 4-10, Para. 3: please state what constant thickness value will be assigned for model layer 2.

    Completed. Statement regarding layer 2 thickness was removed from the text.

28. Please discuss methodology to estimate the recharge for the Permian outcrops.

    Completed. See Section 4.4, first paragraph.

29. Sect. 4.4, Pg. 4-65, Para. 3: There are two references here for Sherrill (1956) that should most likely be Sherrill (1965). Please correct as needed.

    Completed. See Section 4.4, paragraph 3.

30. Sect. 4.4.2.1, Pg. 4-71, Para. 1: Please spell out "Texas Water Development Board" in the reference for consistency with other references.

    Completed. See Section 4.4.2.1, paragraph 1. The abbreviation TWDB is used throughout the document, except for the first time it is used where Texas Water Development board is spelled out and the abbreviation is given.

31. Sect. 4.4.1.2, Pg. 4-70, Para. 2: The last sentence in this paragraph states that "This method…can be used as a regional estimate for recharge because water levels measured in a well should be representative of water levels in a large area around the well." This seems to me to be an overly general statement that may give the wrong impression about the potential for water level variability in the aquifer. Please add clarification, justification, and/or qualification as necessary.

    Completed. See Section 4.4.1.2, first paragraph.

32. Sect. 4.4.2.1, Pg. 4-71, Para. 1: Please provide units for water content in the text "0.04 to 0.06."

    Completed. See Section 4.4.2.1, paragraph 2.

33. Sect. 4.4.1 – 4.4.3: Suggest moving these sections to an appendix and briefly summarizing the methods and results here (or using most of the summary in Sect. 4.4.3). the format of methods, results and discussion, and summary and recommendations does not seem to fit well into the overall scheme of the report.

    No change.

34. Sect. 4.5.1, Pg. 4-91, Para 1: Please spell out "Texas Water Development Board" in the reference for consistency with other references and with the references section. This occurs many times in the report.

    Completed. The abbreviation TWDB is used throughout the document, except for the first time it is used where Texas Water Development board is spelled out and the abbreviation is given.

35. Sect. 4.5.2, Pg. 4-93, Para.1: Please change "where" to "were" in the last sentence.

    Completed. See Section 4.5.2, first paragraph.

36. Sect. 4.5.1, Pg. 4-93: Please add discussion on how the information needed for the streamflow-routing package will be collected (e.g. streambed top and bottom, channel width and slope, Manning's roughness coefficient).

    No change. Information of this type belongs in the model report not the conceptual model report.

37. Sect. 4.6.2, Pg. 4-108, Para. 2: Please add Theis and others (1963) to references section.

    Completed. See Section 6.

38. Sect. 4.6.7, Pg. 4-111, Para. 1: The last sentence states that the specific yield for the Clear Fork and Wichita groups was "assumed to be approximately 0.15." Please provide a source or support for this assumption.

    Completed. See Section 4.6.7.

39. Section 4.7 Are there any estimates of pumping in the Clear Fork Group? Will pumping be included in the Clear Fork Group? If so, per Exhibit B, Attachment 1 page 5 of 24 of contract, please include that information in Section 4.7.

    No change.

40. Figure 4.7.2, page 4-131, Legend – two items are labeled as Municipal, please clarify which is Municipal and which is Rural domestic.

    Completed. See Figure 4.7.2.

Chapter 5.

41. Figure 5.0.1, Pg. 5-8: Please add a line to delineate boundary between Seymour (Layer 1) and Permian (Layer 2) to the upper part of the figure.

    Completed. See Figure 5.0.1.

42. The report states that evapotranspiration is expected to be a very significant portion of the water budget. Please provide detailed discussion regarding evapotranspiration and how it will be implemented in the model.

    No change. Information of this type belongs in the model report not the conceptual model report.

43. Please explain how recharge will be implemented for the both the steady-state and transient periods. Will there be a relationship to precipitation or will recharge be constant and the same for both steady-state and transient periods?

    No change. Information of this type belongs in the model report not the conceptual model report.

Chapter 6.

44. Sect. 6.0, Pg. 6-5: The two Texas Parks and Wildlife (2006 and 2007) references are in the wrong order. Please correct.

    Completed. Texas Parks and Wildlife (2006) should be Texas Parks and Wildlife (2009). Correction made in Section 6.

Source Geodatabase and Figures Comments:

45. Please update the county boundary layer and revise all figures where county boundaries are present.

    Completed. See "counties_SY" feature class and all figures.

46. Please remove duplicate features from the RA_Seymour_Study_Area feature class.

    Completed. See "RA_Seymour _Study_Area" feature class.

47. Figure 2.0.8: Please revise this figure to include a hatched area for the overlap between the two river authorities and add the word "River" after Brazos in the legend.

    Completed. See Figure 2.0.8.

48. Figure 2.1.4: Please include a climate classification feature class. (per Exhibit B Attachment 1, Section 4.2)

    Completed. See "Climate_Class" feature class.

49. Figure 2.1.5: Please add the temperature attribute to the "ave_temp_tx_Griffiths_SY" feature class.

Completed. See feature class 'avg_temp_tx_Griffiths_SY'.

50. Figure 2.1.6: Please add time series data for this figure. (per Exhibit B Attachment 1, Section 4.2)

    Completed. See "Avg_Monthly_Temp" table.

51. Figure 2.1.8: Please add time series data for this figure. (per Exhibit B Attachment 1, Section 4.2)

    Completed. See "Station_Prec_Time_Series" table.

52. Figure 2.1.11: Please add time series data for this figure. (per Exhibit B Attachment 1, Section 4.2)

    Completed. See "Average_Monthly_Lake_Evaporation" table.

53. Figure 2.2.1: Please include a feature class for the Baylor syncline. (per Exhibit B Attachment 1, Section 4.2)

    Completed. See "Baylor_Syn_Poly" feature class.

54. Figure 2.2.4: Please include the high resolution (300 dpi) image used in this figure.

    Completed. See Figure 2.2.4.

55. Figure 4.2.1: Driller's logs from RPGCD seems to be using "sey_base_McGuire" feature class. Please rename feature class in a manner consistent with its representation.

    Completed. See "sey_base_RPGCD_logs" feature class.

56. Figures 4.2.2 through 4.2.5: Data associated with these figures need to be revised because:
    a. The base of the Seymour is above the top in several locations
    b. Raster grids have different resolutions (200 or 660); you should match the model grid cell size since this information will make its way into the model
    c. Raster grids are not aligned to the model grid, or not even aligned with each other; please use the snap raster option when generating these surfaces

    Completed. See "model_grid_update" feature class.

57. Figures 4.3.8 through 4.3.10: The point feature classes: "Seymour_1980", "Seymour_1990", and "Seymour_1997" have corrupted/inaccessible attribute tables. Please revise these feature classes.

    Completed. See "Seymour_1980_Rev", "Seymour_1990_Rev", and "Seymour_1997_Rev" feature classes.

58. Figure 4.4.1: The land use raster dataset should probably be found in the ConservationLandUse raster catalog. The raster dataset does not match this figure. Please add a field with nominal values to describe your reclassification and revise the data to include the missing class.

    Partially completed. The land use raster shown on this figure represents combined National Land Cover Dataset classes as they apply to the evaluation of recharge. Therefore, the raster was not moved from the RechargeGrids raster catalog. A field was added to the land use raster to include the description of the combined land use. The raster data in this figure just applies to the land cover. The irrigated agriculture shown on this figure is a polygon feature class that is separate from the land cover and consists of irrigated areas. Therefore, the irrigated agriculture coverage was not added to the raster. The figure was modified to show that the land use and irrigated agriculture are different. Text was also added to Section 4.4, paragraph six to clarify the content of Figure 4.4.1.

59. Figure 4.4.3: Please include time series data for this figure. (per Exhibit B Attachment 1, Section 4.2)

    Completed. See "haskell_prec_data" table.

60. Figure 4.4.5: Please add tabular data to support these figures. (per Exhibit B Attachment 1, Section 4.2)

    Completed. See "WC_Soil_Type_Comp" table.

61. Figure 4.6.1: The TCEQ feature class has no specific capacity values and we could not locate a feature class for specific yield from county reports. Please revise.

    Completed. See "SC_values_RPBGC_logs", "SC_values_TCEQ_logs", and "Storage_locations" feature classes

62. Figure 4.6.2: Please provide data for this figure. (per Exhibit B Attachment 1, Section 4.2)

    Completed. See "SC_vs_T" table.

63. Figure 4.6.5: It is not clear what data you used to interpolate. The Kh_data_points feature class has duplicate entries for some wells, and the high values in the attribute table were not honored or closely reproduced.

    No change. The duplicate points were counted twice because the represent multiple measurements rather than the same measurement counted twice. The fact that the high values were not (closely) honored has to do with the fact that kriging was used to interpolate the data. Kriging, by definition, has a nugget effect whereby local anomalies will not be honored locally beyond the nugget and not honored elsewhere beyond the scale (1/8 mile by 1/8 mile in the final case) in

any case. Text was added to Section 4.6.5, first paragraph to indicate where the discussion of implementation of hydraulic conductivity in the model can be found in the text.

64. Please include the arbitrary bottom of the Permian-age formations in the geodatabase, provide explanations in the metadata, and include appropriate figures in the report. (per Exhibit B Attachment 1, Section 4.2)

    No change. The bottom of the Permian-age formations is not presented in the report.

65. Per Exhibit B, Attachment 1 page 15 of 24 of contract, please provide tabular data for hydraulic properties and GIS locations of point data. The information shown on Figures 4.6.1 though 4.6.5 is not provided in the geodatabase.

    Completed. See "Hydraulic_Property_Data" table.

SUGGESTIONS

66. Page 1-3, first paragraph, third line, suggest changing "<u>This</u> involves …" to "<u>It</u> involves…"

    Completed with alternative wording. See Section 1.0, paragraph 7.

67. Page 2-1, last paragraph, suggest changing both occurrences of Regional Water Planning Group to Regional Water Planning Area.

    Completed. See Section 1.0, last paragraph, Section 2.0, paragraph 3, and Figure 2.0.5.

68. Page 3-1, 1st paragraph, line 5, suggest changing "(1978) <u>is</u> his report ..." to "(1978) <u>in</u> his report ..''

    Completed. See Section 3.0, first paragraph.

69. Page 4-21, suggest removing paragraph six "The probability ….ago", because this was already stated on page 4-19 at the end of the last paragraph.

    Completed. See Section 4.3.1.

70. Page 4-67, 1st paragraph, line 6 , suggest changing "Table 4.1.1" to "Table 4.4.1".

    Completed. See Section 4.4, paragraph 6.

71. Page 4-67, 2nd paragraph, line 7, suggest breaking paragraph at "The long-term mean annual…", since it is a new topic.

Completed. See Section 4.4, paragraph 8.

72. Page 4-95, section 4.5.3: Lake Davis might not overlay the aquifer boundary, but it does overlay your active area boundary. Please clarify.

    Completed. See Section 4.5.3, first paragraph

73. Page 4-119, section 4.7.1: You state that in western Knox and Haskell counties the Seymour Aquifer discharges to the Brazos River. In Haskell County the aquifer rarely approaches the river. And the only study that quantifies discharge was where the river runs across the aquifer beginning at the border of Knox and Baylor counties. Please provide data/studies to support the statement?

    Completed. Added wording indicting that the aquifer most likely discharges to the Brazos River due to the higher elevation of the aquifer than of the river channel. See Section 4.7.1, paragraph 2.

74. Page 4-71, 1st paragraph, last line, suggest changing “range” to “ranging”.

    Completed. See Section 4.4.2.1, first paragraph.

75. Page 5-1, last paragraph, last sentence, suggest changing “small faction...” to “small fraction …”.

    Completed. See Section 5.0, paragraph 3.

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