Attachment 1

NW Kansas Model Calibration

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Section 1
Introduction

A regional groundwater model was developed by the States of Kansas, Nebraska and Colorado as part of a settlement to the lawsuit filed by Kansas against Nebraska over claimed violations of the Republican River Compact. This groundwater model, referred to as the RRCA (Republican River Compact Administration) Groundwater Model, was developed jointly by the three States over a period of two years between 2000 and 2002. While the joint effort was focused on developing the best model possible and while the calibration process was extensive and comprehensive, the purpose of that model was to predict, with the greatest accuracy possible, groundwater outflows. The groundwater model did not always produce water levels that closely mimicked the measured data.

The lack of correspondence between model water levels and measured data occurred in the Kansas portion of model at some locations and at some times. For example, during some very wet periods, such as the winter of 1992 to 1993, model results did not always track the reduction in the rate of groundwater level decline that was indicated by the measured data. In addition to issues such as these, the data available to the three States in their joint model development effort was limited to pre-2000 measurements. Since 2000, considerable additional water level and stream flow data have been collected that document the ongoing impacts of regional groundwater pumping.

The Kansas Water Office, along with the Kansas Department of Agriculture and the Bureau of Reclamation, were interested in developing a tool to assist in groundwater management within Groundwater Management District #4 (GMD4) in northwest Kansas. Given the efforts that were expended in developing and calibrating the RRCA Groundwater Model, this model was a logical starting point for developing a tool that would be able to evaluate alternative groundwater management scenarios in GMD4.

SSP&A was contracted by the Kansas Water Office and others to refine, update, and recalibrate the RRCA Groundwater Model in the area of northwest Kansas for the purposes of better predicting water levels in northwest Kansas and to analyze alternative groundwater management scenarios in GMD4. This report documents the work conducted by SSP&A in updating the RRCA Groundwater Model and in evaluating alternative groundwater management scenarios in GMD4.

Section 2
Analysis

The first step in updating the RRCA Groundwater Model for the area of northwest Kansas was to recalibrate certain model input parameters for this area. The primary recalibration parameter was groundwater recharge. This effort included extending the calibration period to 2005, augmenting the precipitation station network to include additional gages that were not previously used, and to provide a better estimate of recharge conditions that occurred during some very wet and very dry periods.

The second step in the process was to adjust the model program to better estimate conditions that might occur in the future if severe reductions in aquifer saturated thickness develops. This step included modifying the program code MODFLOW 2000 to account for the reductions in saturated thickness as groundwater levels decline. MODFLOW 2000 is the program used for the RRCA Groundwater Model.

After the model update process was completed, the revised model was used to evaluate alternative groundwater management scenarios in GMD4. This task included developing a 50-year scenario of hydrologic conditions that was representative of historical conditions that had been experienced and might be expected to occur in the future. Alternative groundwater management scenarios were then evaluated using the 50-year scenario of hydrologic conditions.

Recalibration of RRCA Groundwater Model in Northwest Kansas

The recalibration effort focused on two principal objectives; refining the ability of the groundwater model to estimate changes in groundwater levels over time and providing better estimates of groundwater recharge associated with wet and dry periods. The first objective is important because the model will be used to assess continuing groundwater level declines associated with alternative groundwater management scenarios. The second objective is important because the amount of groundwater recharge is an important element in evaluating groundwater management and sustained groundwater development. Since very wet periods can often contribute disproportionately to groundwater recharge, understanding the conditions that occur during these periods can be especially important to improving estimates of groundwater recharge.

Model Recalibration Period

The RRCA Groundwater Model developed by the three States was run over an historical period extending from 1918 to 2000. This period was selected for various reasons, including the fact that it was limited by data available at the time the model was developed. For the model recalibration process, a study period from 1948 to 2006 was used. The end of this period was selected to include more recent data on groundwater conditions. The beginning of this period was selected in part to shorten model runs times and in part to allow the use of additional precipitation gages whose records began after 1948. These additional stations provided better spatial resolution of annual precipitation in the area of northwest Kansas.

Model Recalibration Data

Precipitation Data

Data from additional precipitation stations was provided to SSP&A by the Kansas Department of Agriculture and the Kansas Water Office. In the analysis conducted for the RRCA Groundwater Model, thirty four precipitation stations were used to describe annual precipitation. Eight of these stations were located within northwest Kansas. After reviewing the data for the additional precipitation stations provided to SSP&A, an additional eleven stations were selected to supplement the data used for the RRCA Groundwater Model. This selection was based on the continuity of records for the individual stations. Based in part on this data and the length of records available, a study period of 1948 to 2006 was selected.

The precipitation stations and their locations that were ultimately used in the recalibration process are listed in Table 1. A complete list of the stations and the annual values of precipitation that were used are contained in Appendix A.

Groundwater Levels

SSP&A was also provided with a data base of groundwater level measurements for northwest Kansas. This data base contained almost 34,000 measurements of groundwater levels within the portion of the model domain in northwest Kansas, with data extending from 1948 to 2006. SSP&A organized the data into various worksheets and files for use in the recalibration process. Two worksheets were of particular importance to the process. One of worksheets tabulated the groundwater level elevation data in a form that could be combined with model results to display a comparison between computed groundwater levels and measured groundwater levels at individual well locations. A second worksheet compiled and tabulated changes in groundwater levels over time. In this second worksheet, changes in groundwater levels over different time intervals were compared to the corresponding groundwater level changes computed by the model. Comparisons were made both statistically and graphically to aid in adjusting model parameters and conditions during the recalibration process.

The key worksheets and files that were developed from the data base and used in the recalibration effort are contained on a CD that is attached to this report.

Stream Flows

Stream flow data were not used as the primary recalibration target in this study. Since the recalibration effort was limited to the area of northwest Kansas, the computed stream flows that could be potentially impacted by the recalibration were limited to tributaries such as Beaver, Sappa, and Prairie Dog creeks. During the recalibration process, model results in terms of stream flows were periodically reviewed to be sure that model parameter adjustments were not adversely affecting computed stream flows.

Groundwater Recharge Calculations

Recharge Curves/Power Functions

In the RRCA Groundwater Model, groundwater recharge is estimated using a series of curves that relate annual precipitation to annual groundwater recharge. The various curves are defined by specifying a series of line segments that approximate a curved line. The end points of the line segments specify a value of groundwater recharge for a particular value of annual precipitation. Values of groundwater recharge for values of annual precipitation that fall between end points are linearly interpolated from the values at the end points.

To facilitate the evaluation of recharge curves, the segmented definition used in the RRCA Groundwater Model was replaced by a continuous curve using a power function. The power function had the form: $R = A [(P – Po)^{n} – 1]$, where R is annual groundwater recharge, A is a coefficient, P is annual precipitation, Po is the value of annual precipitation where R equals zero, and n is a value that defines the shape of the curve. Values for the parameters a, Po and n were estimated or calibrated so that the power function closely matched the original segmented curves. These parameters could then be adjusted to test alternative relationships between groundwater recharge and precipitation.

The power function parameters that were used to mimic the segmented curves used in the RRCA Groundwater Model are shown on Table 2. Figure 1 illustrates the comparison between the power function curves and the segmented lines. The soil in northwest Kansas is predominately in the fine category. Thus the power function parameters for the fine soil type have the most influence on the amount of groundwater recharge in northwest Kansas.

Terrain Multipliers/Temporal Adjustments

In the RRCA Groundwater Model, terrain multipliers were used to provide for adjustments to the recharge curves in certain geographic areas. These adjustments were in the form of a scalar multiplier that was applied to the groundwater recharge obtained from the segmented recharge curves. Multipliers were specified at various points throughout the model domain and values at individual model cells were obtained by kriging the values specified at the points. In the RRCA Groundwater Model, most the terrain multipliers at the specified points had a value of one, meaning that the value obtained from the recharge curves was not adjusted. Values other than one were specified at a few points in the eastern part of the model domain within Nebraska.

SSP&A modified the use of terrain multipliers to allow for both a temporal and spatial scaling of the values for groundwater recharge obtained from the recharge curves. In this modification, a different set of terrain multipliers could be specified from one year the next. This modification provided a mechanism for adjusting groundwater recharge during exceptionally wet or dry years and for specifying a geographic distribution to those adjustments. The geographic patterns and amounts of adjustment for different years were determined as part of the recalibration process.

The use of the modified terrain multipliers and the power function recharge curves was implemented through modifications to the program that was developed for the RRCA Groundwater Model to create input files for the MODFLOW program. This program, known as RRPP, creates recharge and pumping files for the RRCA Groundwater Model using various specifications of time period and pumping conditions.

To facilitate the recalibration process, SSP&A developed a companion program to the RRPP program that would separately generate portion of the total model recharge related to precipitation. In the RRPP program, the total recharge input to the groundwater model consists of several components. These include return flows from applied groundwater and surface water and canal seepage associated with imported water, in addition to groundwater recharge from precipitation calculated using the recharge curves. Because of the long run times required for the RRPP program to generate the necessary MODFLOW files, RRPP was used to develop intermediate files that included all inputs except for groundwater recharge from precipitation. This recharge was calculated using a separate program from annual sets of terrain multipliers, annual precipitation distributions and the power function recharge curves. The results of these calculations were then added to the intermediate files to form the final input files for the MODFLOW program.

During the recalibration process, the terrain multipliers were adjusted to try to improve model results, especially in terms of changes in computed groundwater levels over different time periods. The goal of the adjustments was to refine estimates of groundwater recharge from year to year. The adjustments were based on a comparison of the changes in groundwater levels that were observed over different time periods to computed changes over the same periods. The refined set of annual recharge values would ultimately be used to evaluate potential future scenarios of groundwater pumping from the groundwater management district.

Model Recalibration Results

Groundwater Level Hydrographs

The data on groundwater levels provided to SSP&A contained measurements from over 860 wells located within the model domain in northwest Kansas. The data from each of these wells were compared to model results at the location and time of each measurement. These comparisons were then compiled into various statistical and graphical forms to provide a basis for evaluating performance of the model and making adjustments to model parameters and conditions. Some of these comparisons are statistics and graphics that are routinely used to evaluate models. These include scatter diagrams that plot computed versus measured values or various plots of residuals (difference between computed and measured values). Others comparisons have been developed specifically for the northwest Kansas model such as comparisons of water level declines over different time periods. Some of these comparisons are described below. Others are contained in the various worksheets that are provided on the CD attached to this report.

Overall, the calibration of the model to groundwater levels would be considered excellent. The correlation coefficient, which expresses the one to one relationship between computed and measured water levels, was 0.99983. A value for this coefficient of 1.0 would mean that the model was a perfect simulator. The average residual (difference between computed and measured values) for the 33,967 measurements was 1.24 feet. The median residual was 1.51 feet. Ideally, these statistics should be as close to zero as possible to show that the model has little bias. Given the number of measurements, these statistics demonstrate a good model calibration.

The standard deviation (or sometimes termed the standard error) of the 33,967 residuals was 22 feet. The values of measured water levels range from about 1,965 feet to 3,788 feet, a range of over 1,900 feet. The ratio of the standard deviation of the residuals to the range of the measured values is just over one percent. Typically, a ratio of less than ten percent is considered satisfactory. Clearly, the ratio for the northwest Kansas area is more than satisfactory.

Another objective in the model calibration process is to have residuals that are random in space and time. In other words, the objective is to avoid residuals that are predominately positive or negative in a geographic area or over different time periods. In northwest Kansas, the RRCA Groundwater Model produced some trends in residuals over time that remained after the calibration of the RRCA Groundwater Model was completed. One of the goals of the recalibration effort was to evaluate the nature of those trends and to try to make adjustments in model parameters and conditions in northwest Kansas that would reduce those trends.

The recalibration effort was successful in reducing the trend in residuals for northwest Kansas. Figures 2a and 2b illustrate water level residuals versus time for the recalibrated model. Figure 2a is a plot of each of the 33,967 water level residuals versus the time of the measurement. About ninety percent of the computed water levels are within about 30 to 35 feet of the corresponding measured value.

This correspondence is also illustrated on Figure 3, a cumulative frequency chart of the residuals. This chart summarizes the distribution of residuals. Ideally, residuals should be normally distributed about a value of zero. The residuals have a slight positive bias; the median residual is about 1.5 feet. A normal distribution curve has also been plotted on Figure 3 using the mean and standard deviation of the residuals described previously. A comparison with the actual distribution of residuals shows that the standard deviation for most of the residuals is smaller than the computed value for all of the residuals. This indicates that a limited number of larger residuals are skewing the computed standard deviation to some degree. This means that most of the residuals are clustered around the median or average residual more closely than the computed standard deviation would indicate.

The residuals shown on Figure 2a also do not show any discernable trend over time. However, number of measurements clustered about the zero line makes it difficult to discern slight trends. Figure 2b shows the average residual in each calendar year versus time. Again, this plot does not indicate a discernable trend over time. The variation in the average residual is partly related to differences in the number of measurements available in any given year. During the earliest years (prior to about 1950), the number of measurements in any given year was generally less than a few hundred. During the mid to late sixties and early seventies, over 1,000 measurements were available in each year. Since that time, the number of measurements available in each year generally ranged from about 400 to 600.

Typically, model results are evaluated using a scatter diagram which plots computed values versus measured values. Ideally, the values would lie along and very near to a 45-degree line. A scatter diagram for the recalibrated northwest Kansas model is shown on Figure 4. The overall correspondence between the computed and measured values is obviously very good. This observation is consistent with the correlation statistic of 0.99983 referred to previously where a value of 1.0 would indicate perfect correlation.

While the scatter diagram provides one measure of model calibration, the wide range in measured values of groundwater level elevation (about 1,900 feet from 1,900 feet to 3,800 feet) can obscure the correspondence between values over time at individual well locations. Also, calibrating only to groundwater level elevations when the range in elevations is large can reduce the sensitivity of the process to changes in groundwater levels over time at individual well locations.

Water Level Change Data

In order to provide more focus on changes in groundwater levels over time at individual wells, a second calibration data set was constructed. One of the objectives for the recalibrated northwest Kansas model is to provide a tool for assessing the future impact of water management decisions such as limiting or curtailing future pumping. Thus the ability of the model to predict changes in groundwater levels associated with pumping is an important feature. In the development of the RRCA Groundwater Model, the calibration process included examining both groundwater levels and changes in groundwater levels. However, the examination of water level changes over time was largely qualitative through visual evaluations of computed and measured water level hydrographs. Also, the RRCA Groundwater Model was developed specifically to estimate stream flow depletions and the calibration was therefore focused on comparing computed and measured base flow and changes in base flow. While changes in base flow are one component of pumping impacts in northwest Kansas, changes in groundwater levels are more important from the standpoint of groundwater management.

The groundwater level data base provided to SSP&A was used to develop data sets of water level changes over seven time periods. The time periods were 1964-2006, 1970-2006, 1970-1980, 1980-1990, 1990-2000, 2000-2006 and 1990-2006. These periods were selected to examine the ability of the model to predict changes over longer time periods as well as changes within increments of the longer periods. Since measured data are more sparse during earlier periods, the earliest time was limited to 1964 so that enough of the wells had measurements (at both the beginning and the end of the period) to make a comparison worthwhile. Generally, the number of wells with data at both ends of a period increased as time goes on. There were 123 wells with data spanning from 1964 to 2006 and 333 wells with data spanning from 2000 to

2006. Together, these data sets provide a comprehensive measure of groundwater level changes that have occurred in northwest Kansas since 1964.

Results from the recalibrated northwest Kansas groundwater model were compiled and compared to the water level changes over the seven time periods. A summary of the statistics of that comparison for the calibrated model are shown on Table 3. A worksheet containing additional statistical and graphical comparisons of the water level changes is provided in the CD attached to this report.

As shown by the various statistics compiled on Table 3, results from the recalibrated northwest Kansas groundwater model compare well with the measured water level changes over the selected periods. This comparison is a more indicative test of the ability of the model to predict changes in groundwater levels. More importantly, these results represent an improvement over the comparable results using the RRCA Groundwater Model. That model showed a tendency to over predict water level declines over the longer periods and to under predict water level declines during some of the shorter periods. As shown on Table 3, the average residuals for all the periods are near zero indicating a lack of bias. The standard deviation of the residuals is generally less than ten percent of the range in the values. This is a metric that is commonly used to characterize model performance. Correlation coefficients are generally high, especially for the longer time periods. The correlation coefficients are lower than the value obtained by comparing only the groundwater levels (0.99983). This demonstrates that predicting water level changes is generally a more robust test of model performance than predicting groundwater levels.

In summary, the recalibration process has resulted in a model for northwest Kansas that is capable of predicting both shorter term and longer term water level declines with about the same level of accuracy. Thus the revisions to model parameters and conditions provide a more reliable description of historical groundwater conditions and changes in those conditions over time.

Alternative Groundwater Management Scenarios

Pumping Limitations and Reductions

The recalibrated northwest Kansas groundwater model was used to evaluate three scenarios of future groundwater development in GMD4. Six subareas within GMD4 were delineated for evaluation. A 50-year sequence of hydrologic conditions (groundwater recharge and pumping) was established to test each of the scenarios. The three scenarios consisted of 1) continued pumping within the subareas at current levels, 2) curtailment of all pumping within the subareas, and 3) a thirty percent reduction in pumping within the subareas. For each of the scenarios, the groundwater model was used to estimate future changes in groundwater levels and saturated thickness within the subareas. Groundwater budgets for each scenario were developed and compared to illustrate the impacts of the different water management strategies.

Representative 50-year Hydrologic Sequence

A representative 50-year sequence of hydrologic conditions was developed to provide for an evaluation of alternative groundwater management scenarios. Simply assuming average conditions for the foreseeable future provides some measure of future expectation but will not reflect variations over dry and wet hydrologic cycles. In order to provide some level of hydrologic variation to the evaluation, a simple process was used to develop a variable and representative sequence of future hydrologic conditions.

The future sequence was developed in several steps. First, a cumulative frequency distribution of the estimated groundwater recharge in northwest Kansas from the recalibrated groundwater model for the years 1948 to 2005 was prepared. Next, a pseudo 58-year cumulative frequency distribution was constructed using annual recharge values from only the years 1990 to 2005 that had a shape that was approximately equivalent to the actual 58-year distribution for 1948 to 2005. The years from 1990 to 2005 were selected because data from those years would be more representative of current conditions with regard to groundwater pumping and irrigated acreage. The average annual recharge for the pseudo 58-year distribution was about 210,000 acre feet per year while the average annual recharge for the actual 58-year distribution was about 209,000 acre feet per year. As a result the pseudo 58-year distribution had approximately the same frequency of high and low recharge conditions and had approximately the same overall annual average recharge. The actual 58-year distribution and the pseudo 58-year distribution are shown on Figure 5.

The pseudo 58-year distribution was then used to construct random 50-year sequences of groundwater recharge for northwest Kansas. Fifty values were randomly drawn from the 58-year distribution over and over again. Each random 50-year sequence was then evaluated qualitatively and quantitatively. One of these sequences was then selected that had characteristics that would allow for a reasonable evaluation of future groundwater management scenarios. One characteristic was that the sequence had to have an average annual groundwater recharge that was similar to the longer-term average recharge obtained from the recalibrated northwest Kansas model. Another characteristic was that the sequence had consecutive years of both wet and dry hydrologic conditions.

The selected 50-year hydrologic sequence of groundwater recharge is shown on Figure 6. Also shown on this figure for comparison is the actual groundwater recharge for the 50-year period from 1956 to 2005. While the actual period from 1956 to 2005 could have been used as a 50-year sequence, groundwater pumping and irrigated area were much less during the early part of that period and would not be representative of current conditions. In order to evaluate future groundwater management scenarios, conditions need to reflect the current status in order to evaluate how changes in the current status will affect future conditions.

Adjustments to Pumping

The development of future scenarios focused on using recent historical data in order to make the scenarios representative of current water use practices. However, changes in these practices have occurred even within the recent period that was selected. Adjustments to historical data on pumping and groundwater return flows over the period from 1990 to 2005 were made to account for these changes in future scenarios.

The historical pumping data for the years 1990 to 2000 were adjusted separately from the data for the period from 2001 to 2005 due to the availability of point of use information. Prior to 2001, certain point of use information was not available and use was assumed to occur at the point of diversion. After 2000, pumping was associated with the point of diversion while return flow and irrigated area were associated with a known place of use.

Apart from the differences in pumping data described above, several other adjustments were made to data for each year to better reflect current irrigation conditions. These adjustments included 1) adjusting irrigated area in the Almena district, 2) reducing the amount of unmetered pumping to better reflect information from metered data, 3) reducing groundwater return flow ratios to values commensurate with 2005 conditions, and 4) increasing overall pumping, irrigated area and return flow to represent slightly increased development over the period. The purpose of these adjustments was to develop data sets of pumping, irrigated area, and return flows that would reflect both the climatic conditions that existed during each of the years and the current level of irrigation development and practice.

MODFLOW 2000 Modifications to Account for Reduced Saturated Thickness

One concern from a groundwater management perspective is reductions in saturated aquifer thickness associated with declines in groundwater levels. The RRCA Groundwater Model was developed using a temporally constant saturated thickness. Since the principal purpose of the RRCA Groundwater Model was to estimate depletions to stream flow caused by regional pumping, the effect of decreasing saturated thickness was not a critically important issue. In terms of issues associated with groundwater management in GMD4, however, the effect of decreasing saturated thickness is more important.

The inclusion of a dynamic saturated thickness in a groundwater model is conceptually straightforward but can be problematic in practice. This can be especially true for a regional model where the lateral scale is much larger than the vertical scale. Oftentimes, allowing the saturated thickness to vary as a function of computed groundwater levels can create numerical instability that causes the numerical solution process to disintegrate.

For the northwest Kansas groundwater model, the MODFLOW program was modified in a way that allows the effect of reduced saturated thickness to be considered without creating adverse numerical instability. The modification consisted of adjusting the transmissivity associated with a baseline condition based on the ratio of water level changes from the baseline condition to the saturated thickness associated with the baseline condition.

The modification was implemented by comparing the computed groundwater level at the beginning of each time step to the groundwater level associated with the steady state result obtained from the first time step. The difference in these water levels was then used to adjust the saturated thickness that was specified by the top and bottom elevations in the input data set. The transmissivity was then adjusted accordingly to reflect the new saturated thickness. A minimum saturated thickness of ten feet was imposed to prevent model cells from being eliminated. The adjustments were made at the beginning of each model time step. This procedure helped to eliminate the instability that is often associated with invoking the unconfined option in the MODFLOW model.

Model Subarea Conditions

Subarea Definitions

Six subareas within GMD4 were selected to evaluate water management alternatives. GMD4 encompasses about 4,896 square miles. The six subareas cover about 533 square miles or about eleven percent of the area of GMD4. The locations of the six subareas within GMD4 are shown on Figure 7. The individual subareas range in size from 9 square miles to 243 square miles.

During the period from 1996 to 2005, the average pumping within GMD4 was about 411,000 acre-feet per year. During this same period, pumping from the six subareas averaged almost 109,000 acre-feet per year which is nearly twenty seven percent of the total pumping within GMD4. Pumping from the individual subareas ranged from about 1,000 acre-feet per year to nearly 38,000 acre-feet per year.

The average total annual pumping rate within the six subareas over the period from 1990 to 2005 that was used to construct the future 50-year sequences described previously was about 102,000 acre-feet per year. Adjustments to historical pumping rates described previously to reflect current irrigation patterns and conditions increased that average to about 104,000 acre-feet per year.

Future Pumping Scenarios

Three scenarios of future pumping within the six subareas were evaluated using the recalibrated northwest Kansas groundwater model. In scenario 1, which is a continuation of current conditions, the average pumping for the 50-year future hydrologic was about 104,000 acre-feet per year. In scenario 2, all of the pumping from the six subareas except for municipal pumping was eliminated. The remaining pumping for the six subareas in this scenario was about 1,100 acre-feet per year. In scenario 3, pumping from the six subareas was reduced by thirty percent. The average pumping from the six subareas over the 50-year hydrologic sequence for this scenario was about 73,000 acre-feet per year.

Recharge from precipitation for the three scenarios was the same except for the increase in precipitation recharge associated with irrigated land. The curves used to quantify precipitation recharge are different for irrigated land versus non-irrigated land. In the future pumping

Scenario 2, the amount of irrigated land was reduced to reflect the reductions in pumping. In Scenario 3, the irrigated acreage was not reduced presuming that the reduction in pumping would not reduce irrigated acreage but merely reduce the amount of water applied to the existing acreage. In Scenario 1, total annual recharge to the six subareas averaged about 29,000 acre-feet per year. This total includes return flow from applied groundwater, recharge from precipitation and increased recharge from precipitation on irrigated land. Of the 29,000 acre-feet per year, all but about 9,000 acre-feet per year is associated with return flow from applied groundwater and increased recharge from precipitation on irrigated land.

In Scenario 2, where all of the irrigation pumping was removed, the total average annual recharge for the six subareas was about 9,000 acre-feet per year. This represents the total annual average water supply that is perennially available from within the area of the six subareas. The reduction in total recharge from Scenario 1 is about 20 percent of the total reduction in irrigation pumping in Scenario 2 versus Scenario 1.

In Scenario 3, where pumping was reduced by 30 percent, the total annual average recharge was reduced by about 6,000 acre-feet per year to an average of about 23,000 acre-feet per year. This reduction corresponds to about 20 percent of the amount of reduction in pumping between Scenarios 1 and 3. Thus, the total net return flow associated with irrigation is about 20 percent of the amount of applied irrigation water. Most of this 20 percent is return flow from the applied groundwater. The remainder is the increase in recharge from precipitation on irrigated land.

Subarea Output Compilations – Water Levels and Water Budgets

The computed results for each of the three future water management scenarios were compiled into various maps and tables to illustrate the projected impacts for each scenario over the selected 50-year future hydrologic sequence. The compilations included maps of projected future water level declines and saturated thickness within the northwest Kansas area and tabulations of projected groundwater budgets for each of the six subareas over the 50-year future period. All of the maps are included on the CD attached to this report in the form of the Surfer mapping file. Similarly, various Excel worksheets summarizing the groundwater budget compilations are on the attached CD. Some of the maps and groundwater budget tabulations are discussed below.

Results for Alternative Scenarios

Water levels – Maps and Tabulations

Average groundwater levels within the six subareas are projected to decline on between 28 and 58 feet over the next 50 years under Scenario 1. A map showing the distribution of the projected groundwater level declines over the 50-year period is shown on Figure 8. As shown on this figure, the largest declines are projected to occur in the central parts of Sherman and Thomas counties and in the western part of Sheridan County. A comparable map of the projected changes in groundwater levels over the 50-year period for Scenario 2 is shown on Figure 9. By eliminating irrigation pumping within the six subareas, the projected groundwater level declines noted in Scenario 1 have largely been reduced or eliminated within the subareas and, in some areas, groundwater levels are projected to increase over the 50-year period. However, these reductions in groundwater level declines are generally limited to the subareas where irrigation pumping was eliminated. Outside the subareas, groundwater levels are projected to continue decline in response to continued pumping outside the subareas. Projected groundwater level changes under Scenario 3 are shown on Figure 10. As shown on this figure, groundwater levels are projected to continue to decline within the six subareas. However, the amount of decline over the 50-year period is estimated to be about 10 to 30 percent less than the decline projected for Scenario 1. This reduction in groundwater level decline represents the effect of reducing irrigation pumping within the subareas by thirty percent.

The declining groundwater levels projected under Scenarios 1 and 3 will produce commensurate reductions in saturated thickness. Maps of saturated thickness as calculated by the northwest Kansas groundwater model are shown on Figures 11 through 14. Figure 11 shows the calculated saturated thickness at the end of 2005. This represents the available saturated thickness at the beginning of the 50-year future simulation period. The average saturated thickness within the six subareas ranges from about 80 to 150 feet. Of particular interest is the subarea in the central part of Thomas County where saturated thickness in 2005 is estimated to be less than 40 feet.

Figure 12 shows the projected saturated thickness in 2055 under Scenario 1. The aquifer in the central part of Thomas County where saturated thickness was less than 40 feet in 2005 is projected to be dewatered by 2055. In fact, dewatering of the aquifer in this area is projected to begin within about 20 years under Scenario 1.

It should be noted that in the northwest Kansas groundwater model, actual dewatering of the aquifer is precluded by a limit on how much the transmissivity is allowed to decline. The modifications to the MODFLOW program to adjust transmissivity as water levels change were set up to limit the reduction in saturated thickness for purposes of calculating transmissivity to 10 feet. What this means is that aquifer transmissivity is never allowed to decline below 10 feet times the hydraulic conductivity at any model grid cell and model grid cells are never allowed to become inactive. The purpose of this logic is to allow pumping and groundwater recharge to continue so the effect of a given pumping level can be fully evaluated. In practice, it is likely that pumping may be curtailed when saturated thickness and transmissivity decline below levels necessary to sustain well capacity. However, groundwater recharge would continue to occur even if the aquifer is dewatered. Designating a model cell as inactive when dewatering occurs would lead to incorrectly eliminating some groundwater recharge unless adjustments to the MODFLOW program were made to account for this recharge.

The actual response of irrigators to declining transmissivity is not clear. As transmissivity declines and well capacity decreases, irrigators may simply operate wells at lower rates for longer times in order to achieve a desired amount of applied water. In any case, the current model formulation does not adjust the pumping in response to decreasing saturated thickness and aquifer transmissivity. In order to consider such adjustments, an algorithm would need to be developed to estimate how irrigators would likely respond to reduced well capacity. If an algorithm can be developed, modications to the MODFLOW program can be made to estimate how pumping might be impacted by declining groundwater levels and reduced saturated thickness.

Figure 13 shows the projected saturated thickness in 2055 under Scenario 2. In this scenario irrigation pumping was eliminated within each of the six subareas. Under this scenario, the trend of continued groundwater level declines is reduced considerably and even reversed within the subareas. Groundwater levels are projected to continue declining in areas outside the subareas where irrigation pumping was eliminated in response to continued pumping in those areas.

Figure 14 shows the projected saturated thickness in 2055 under Scenario 3. In this scenario, irrigation pumping was reduced by thirty percent within each of the six subareas. Under this scenario, aquifer dewatering is still projected to occur in some areas such as the central part of Thomas County, although the extent of dewatering is less than that projected under Scenario 1.

Trends in Groundwater Level Declines

Historically, groundwater levels in northwest Kansas have been declining since the late 1960s and early 1970s. As shown on Table 3, groundwater levels have declined as much as about 80 feet in places since the mid-1960s. These declines are projected to continue in the future at varying rates depending on trends in future pumping. To further illustrate potential future declines within GMD 4, a series of hydrographs have been developed for different well locations within the district. The locations of selected wells are shown on Figure 15. Wells having long measurement histories were preferentially selected to allow model results for the historical period to be compared with measured water levels. The projected groundwater levels for each of the three future scenarios were added to the model results for the historical period to allow for a comparison of trends for each of the future pumping scenarios.

Hydrographs for each of the locations shown on Figure 15 are shown on Figures 16-a through 16-k. Each hydrograph shows the measured water levels (blue square symbols) and model results for the historical period (red square symbols). The hydrographs also show the adjusted model results for the historical period (green cross symbols). The model results were adjusted by the average difference between the model results and the measured water levels. The adjustment shifts the model results to a vertical position that is more closely aligned with the measured water levels. This allows for an easier comparison of the temporal trend in the model results as compared to the temporal trend in the measured water levels.

The projected groundwater levels for each of the three future scenarios are shown on the hydrographs as an extension of the model results beyond the historical period. On each hydrograph, the results for Scenario 1 are depicted with red cross symbols, results for Scenario 2 are depicted with light blue cross symbols, and results for Scenario 3 are depicted with dark blue cross symbols. Generally, the results for the three scenarios are relatively easy to distinguish as the greatest future declines are projected under Scenario 1 (continuation of status quo conditions) and the least future declines are projected under Scenario 2 (termination of irrigation pumping within each the six subareas). Results for Scenario 3 (30 percent reduction in irrigation pumping) within each of the six subareas) fall in between the results for Scenarios 1 and 2.

As one might expect, differences in the trends of projected future groundwater level declines varies depending on the proximity to areas where there are significant differences in pumping among the three scenarios. At well locations that are more distant from the larger subareas (such as wells 545, 655, or 765), future trends for the three scenarios are fairly similar. At well locations within the larger subareas (such as wells 594. 603 or 717), water level declines are projected to generally stabilize or perhaps recover slightly under Scenario 2. At well locations near the Kansas-Colorado border (such as well 509), declines are projected to largely continue under all scenarios in spite of the well's proximity to one of the larger subareas. This is due to the continuation of pumping in Colorado at rates comparable to recent historical amounts.

Water Budget Tabulations

Groundwater budgets for each of the six subareas were compiled to characterize the relationship between recharge, storage depletion and groundwater inflow in response to pumping. Table 4 shows the groundwater budgets for Scenarios 1 and 2. The values on Table 4 are averages over the 50-year future hydrologic sequence. The differences in the budget values between Scenario 1 and Scenario 2 are also shown on Table 4. The differences show the effect of implementing a particular groundwater management scenario.

The sources of supply to groundwater pumping within the subareas are clearly shown on the table. The groundwater pumped from within each subarea under Scenario 1 is derived principally from depletion of aquifer storage. The remainder of the pumping that is not derived from depletion of storage is supplied by groundwater recharge within the subareas and groundwater inflow into the subareas from surrounding areas. Some of the groundwater inflow from surrounding areas is also derived from storage depletion in areas outside the subareas.

Under Scenario 2, almost all of the pumping within each of the subareas has been eliminated. The remaining pumping under this scenario corresponds to municipal pumping that occurs within the subareas. Note that net storage depletion continues to occur within the subareas under this scenario in response to continued pumping outside the subareas. The groundwater inflow to the subareas under Scenario 1 changes to groundwater outflow under Scenario 2.

Note also that groundwater recharge under Scenario 2 is significantly less than that under Scenario 1. This is due to the reduction in irrigated area associated with the elimination of irrigation pumping and the elimination of groundwater return flow associated with applied irrigation water. Groundwater recharge from precipitation is also considered to be less on irrigated land versus non-irrigated land. This difference is created by the difference in the curves used to estimate recharge from precipitation on irrigated versus non-irrigated land.

Table 5 compares groundwater budgets for each of the six subareas for Scenarios 1 and 3. In general, the differences between budget components for Scenarios 1 and 3 are simply scaled versions of the differences between Scenarios 1 and 2 shown on Table 4. This approximate linear scaling means that alternative reductions in pumping from the subareas (such as 20 or 40 percent) can be expected to produce approximately proportional changes in the water budget components.

Section 3
Conclusions and Recommendations

Based on the analyses described in this report, recalibration of the RRCA Groundwater Model and evaluation of future management scenarios for Groundwater Management District #4 leads to the following conclusions and recommendations.

Recalibration has improved model performance in predicting groundwater levels and changes in groundwater levels in the northwest Kansas portion of the RRCA Groundwater Model.

The recalibrated model can be used to assess impacts from future groundwater use in northwest Kansas.

Future recharge and pumping scenarios reflect potential recharge and pumping conditions that are consistent with historical climatic variations and reflect the current status and conditions of groundwater use in northwest Kansas.

Within the six subareas of GMD 4, groundwater pumping is supplied by groundwater storage depletion associated with declining groundwater levels, groundwater recharge from precipitation within the subareas, and groundwater flow from surrounding areas into the subareas.

Future declines in groundwater levels within the six subareas of GMD 4 are projected to be about 10 to 30 percent less under Scenario 3 as compared to Scenario 1.

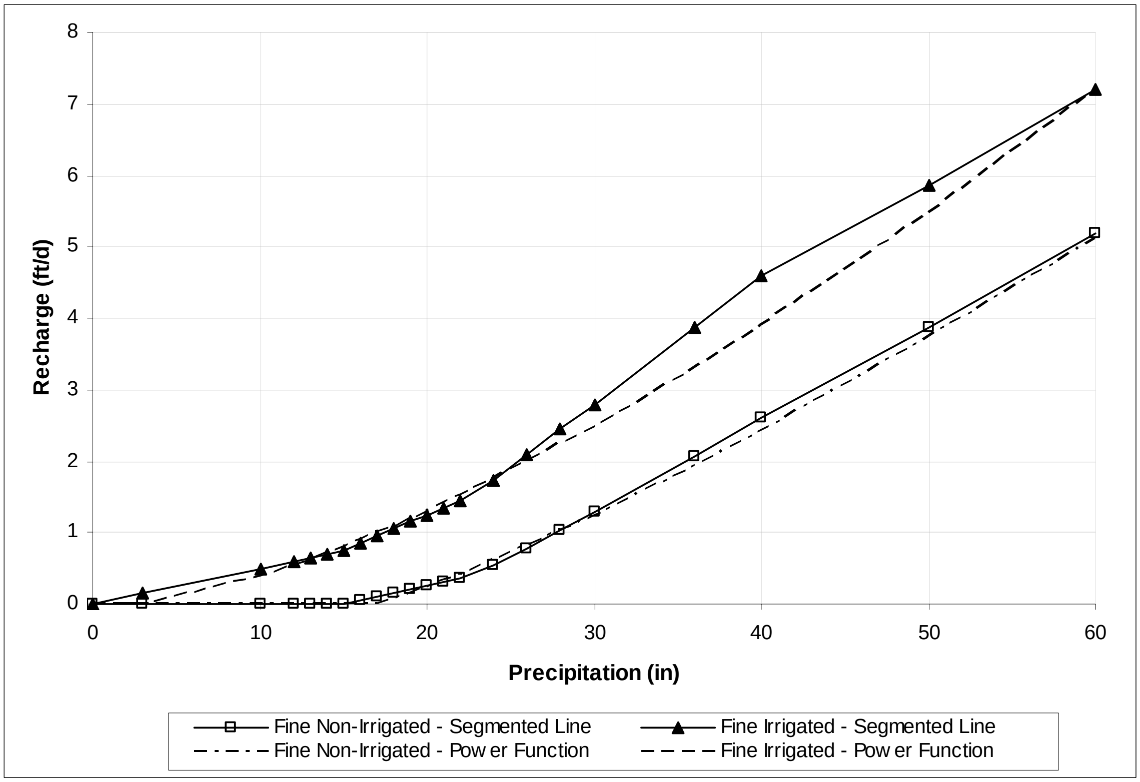

Figure 1: Comparison between Power Function Curves and Segmented Lines (Soil Type: Fine).

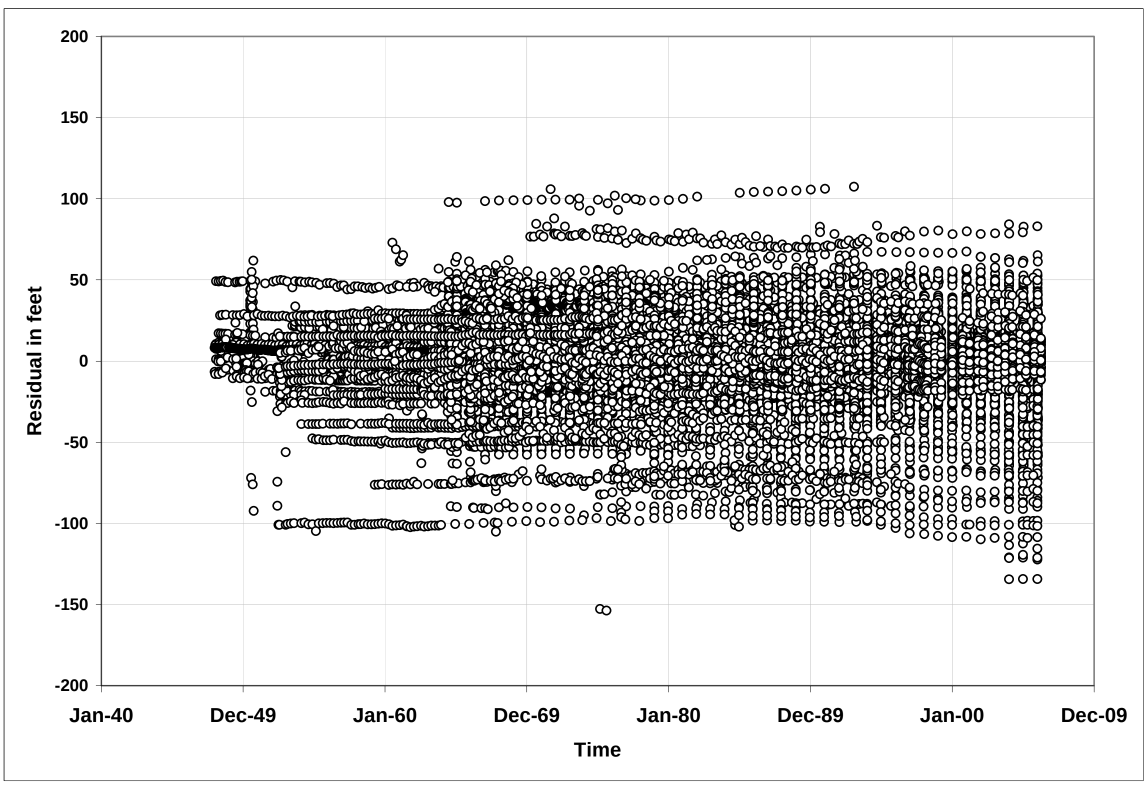

Figure 2a: Water Level Residual versus Time.

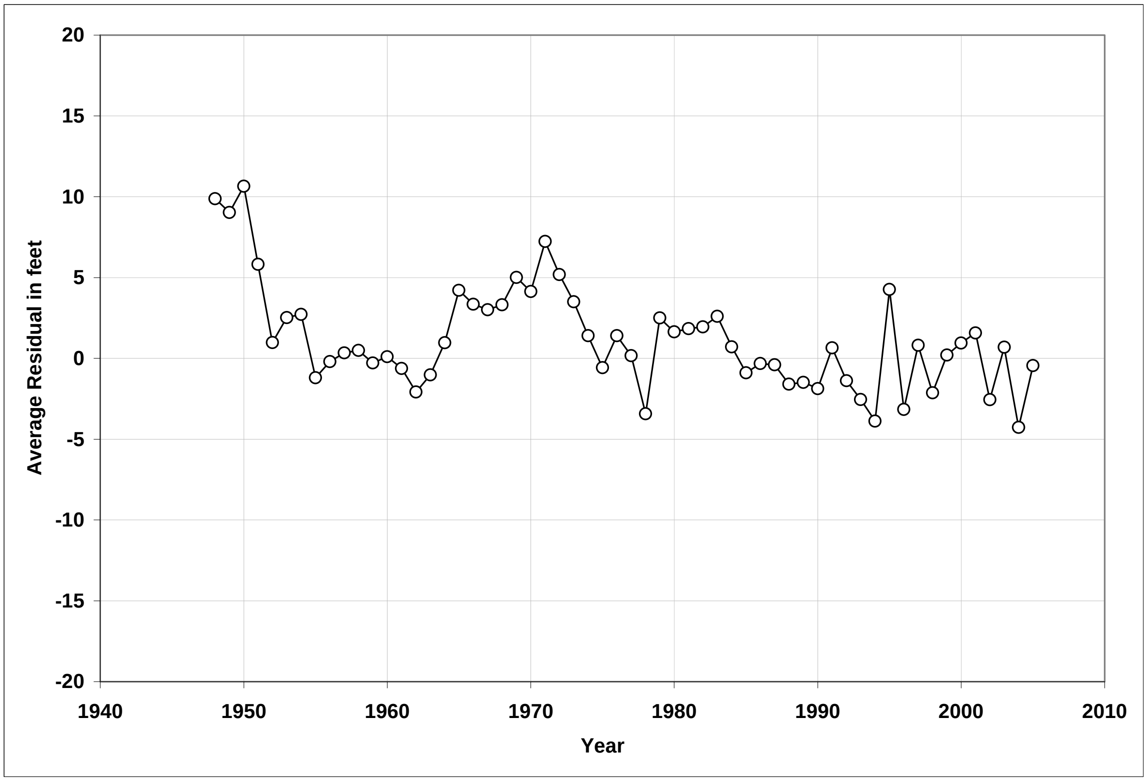

Figure 2b: Average Annual Water Level Residual versus Time.

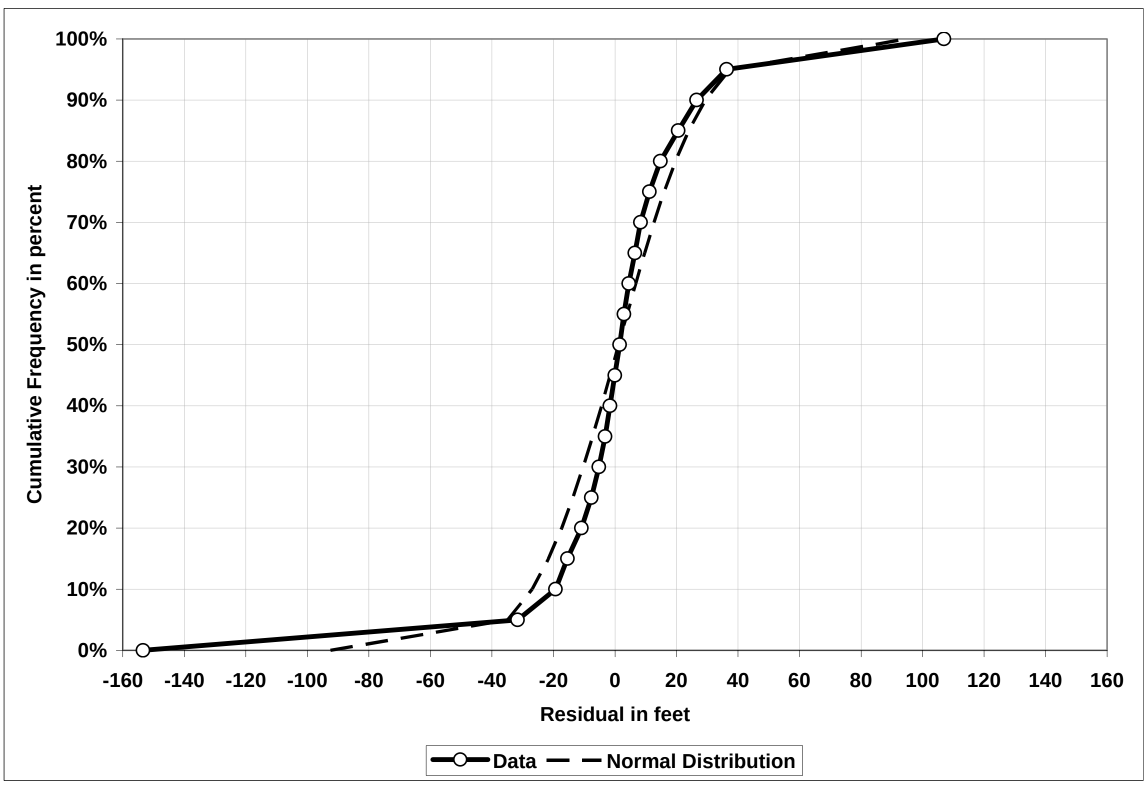

Figure 3: Cumulative Frequency of Water Level Residuals.

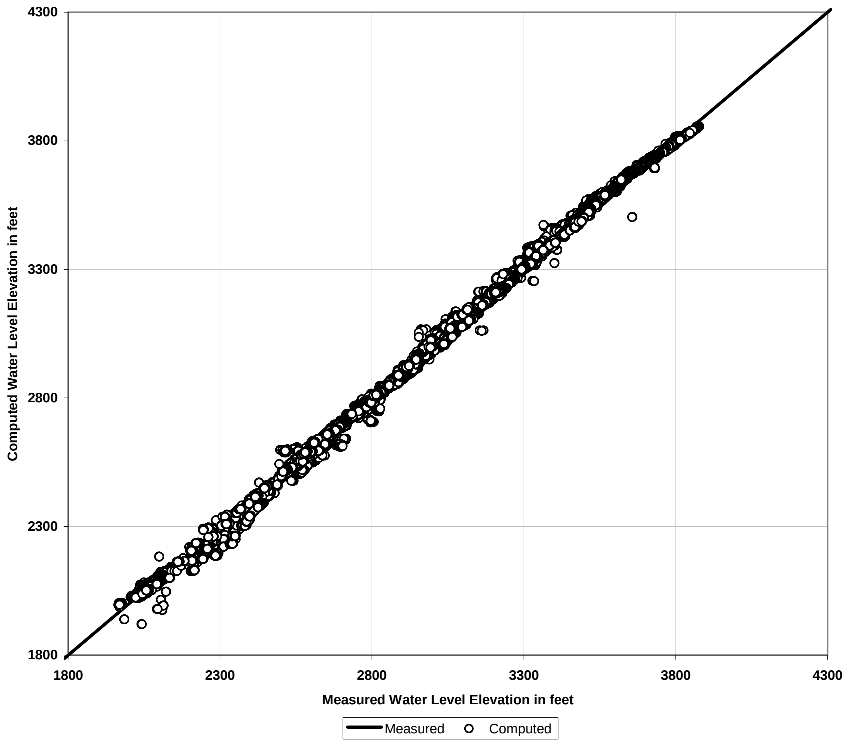

Figure 4: Scatter Diagram.

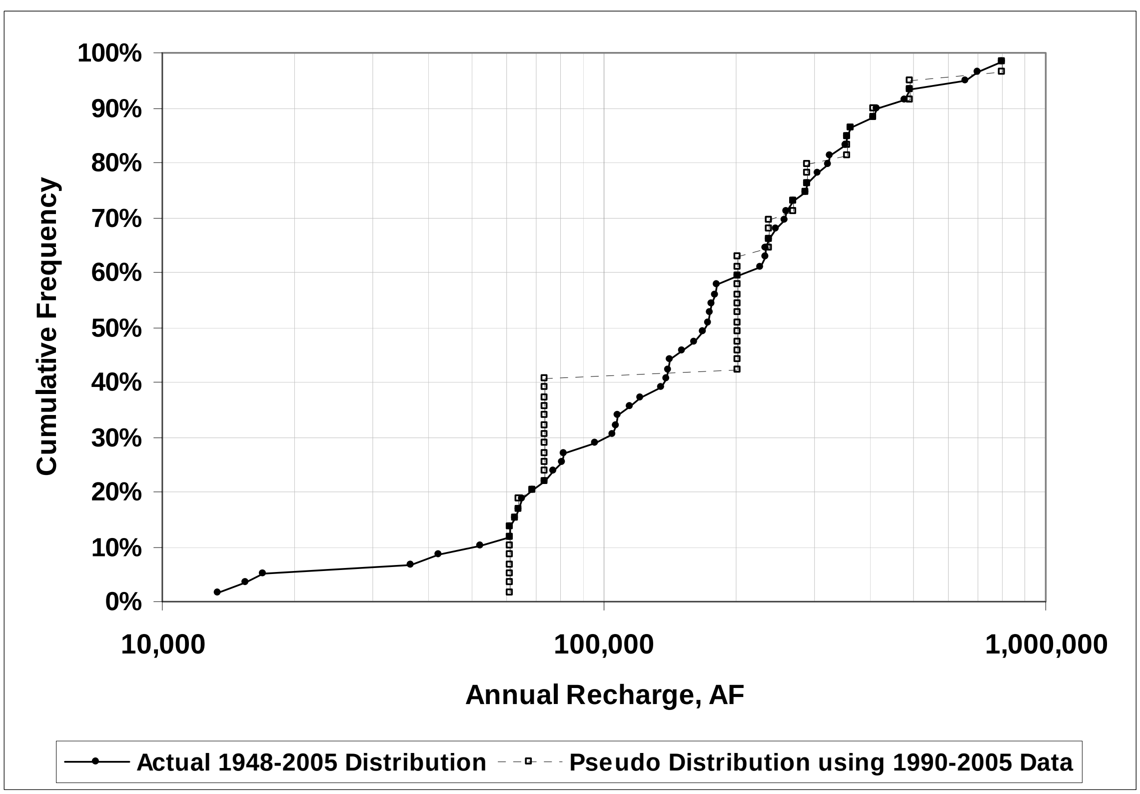

Figure 5: Annual Recharge – Actual and Pseudo Distributions.

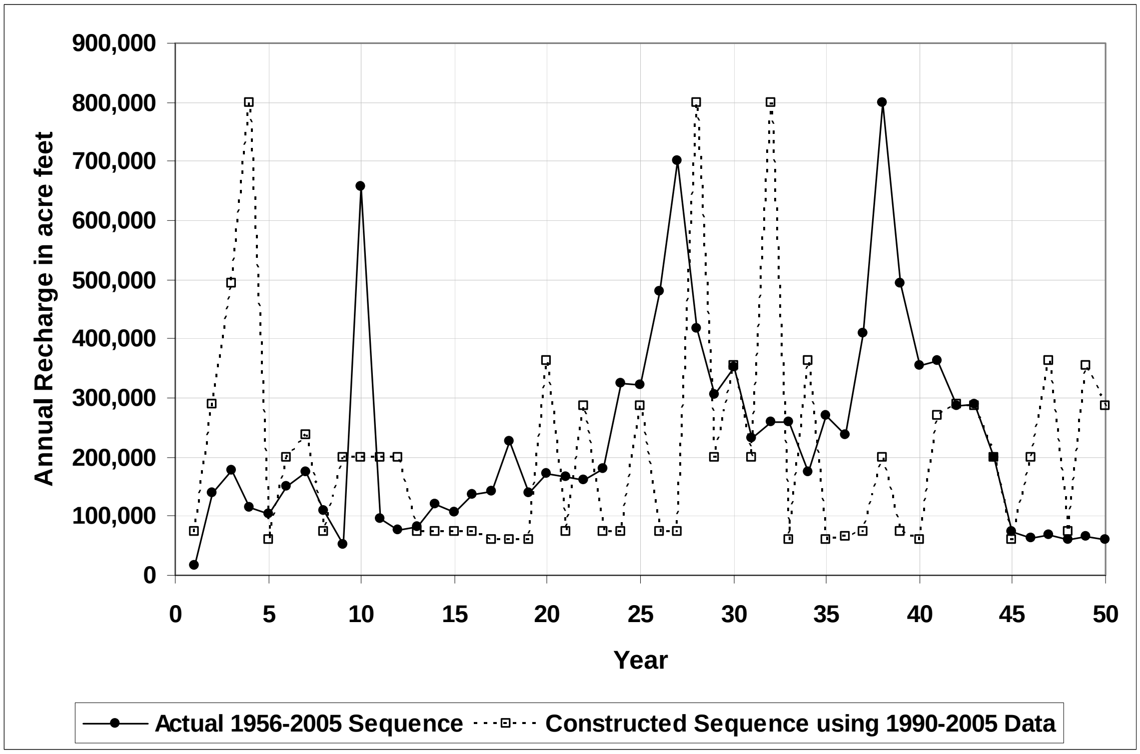

Figure 6: Annual Recharge – Historical and Future Sequence.

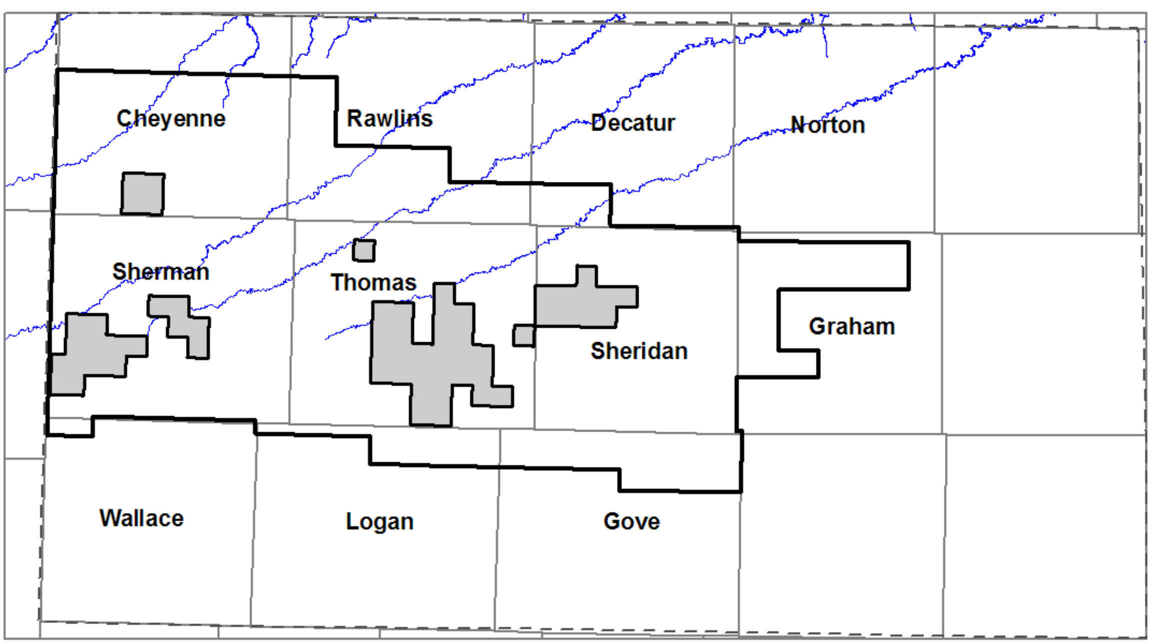

Figure 7: Map showing Subareas within GMD 4.

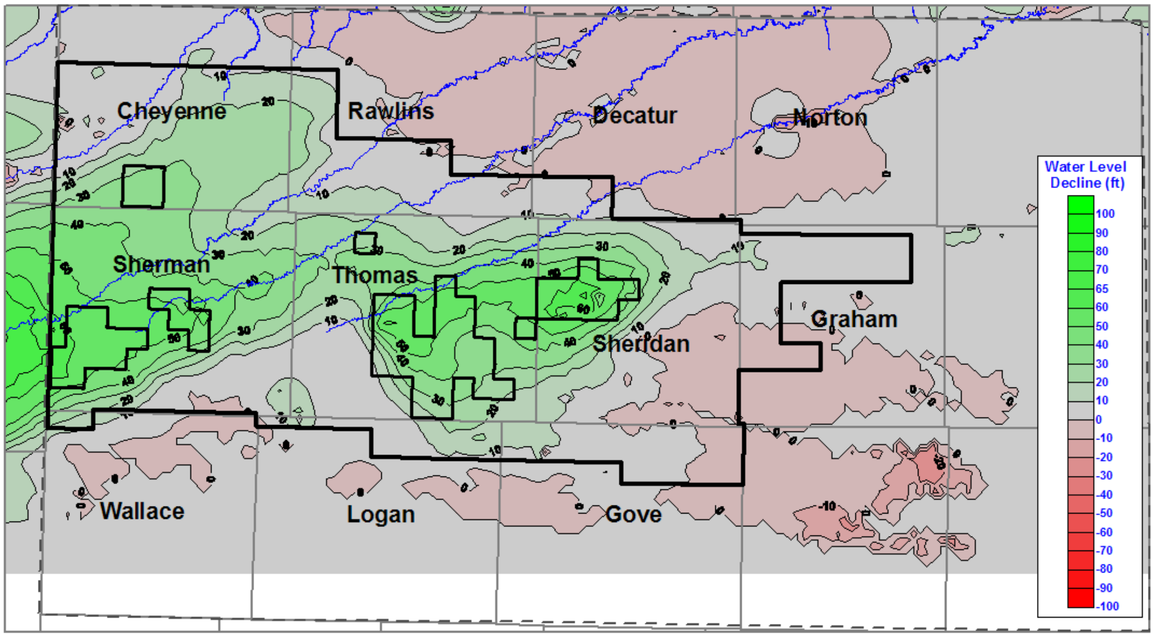

Figure 8: Projected 50-Year Water Level Decline - Scenario 1.

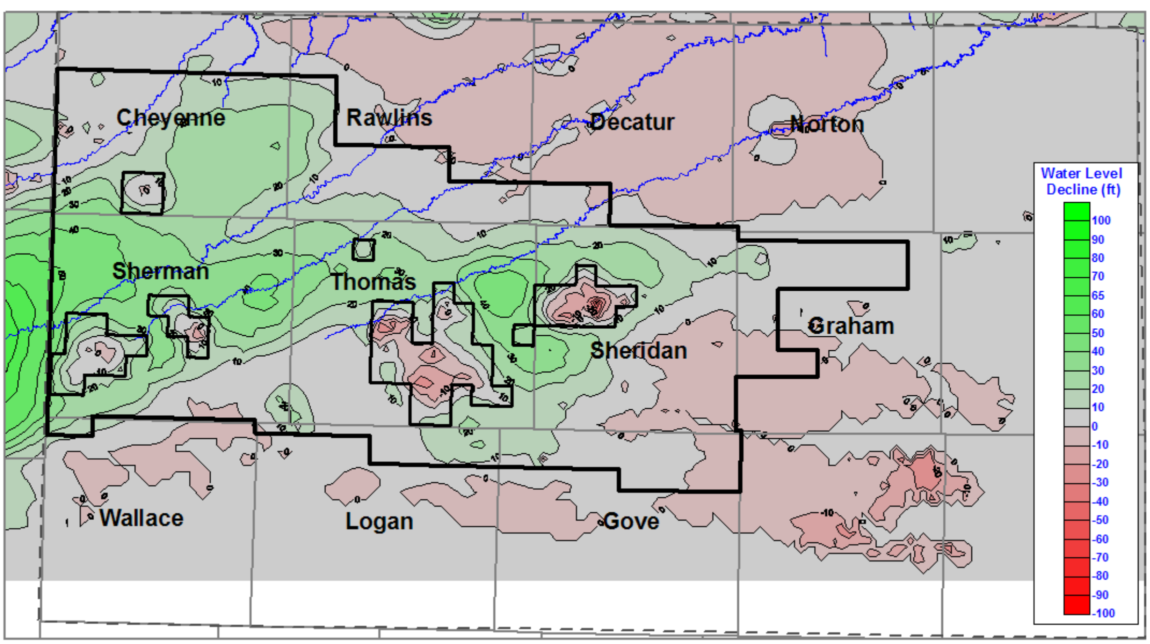

Figure 9: Projected 50-Year Water Level Decline - Scenario 2.

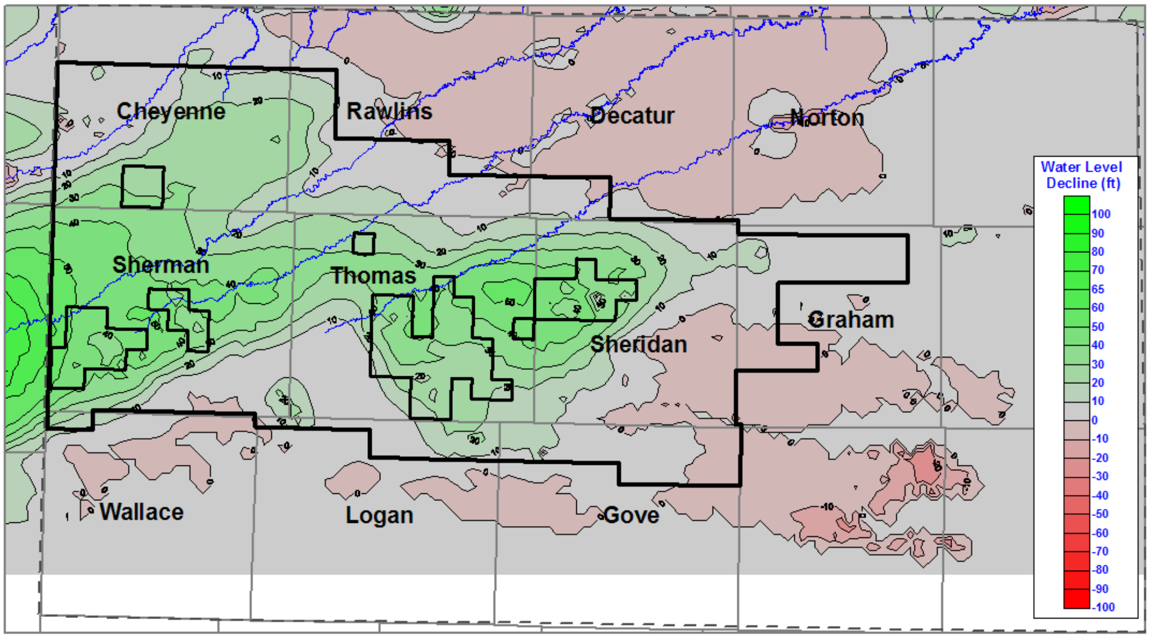

Figure 10: Projected 50-Year Water Level Decline - Scenario 3.

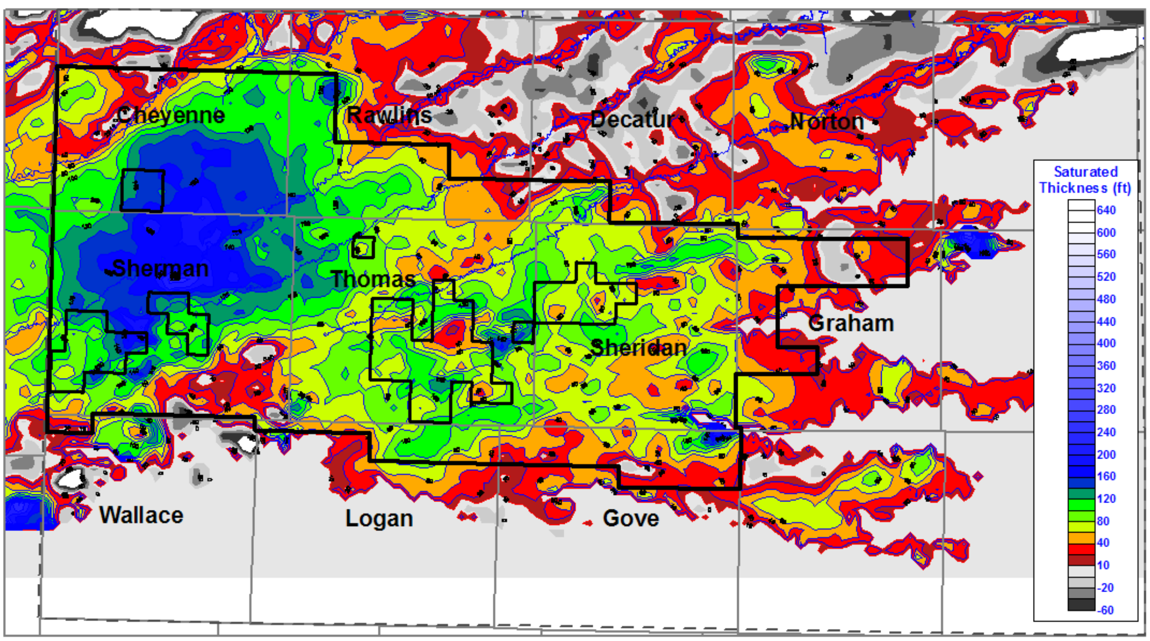

Figure 11: 2005 Saturated Thickness.

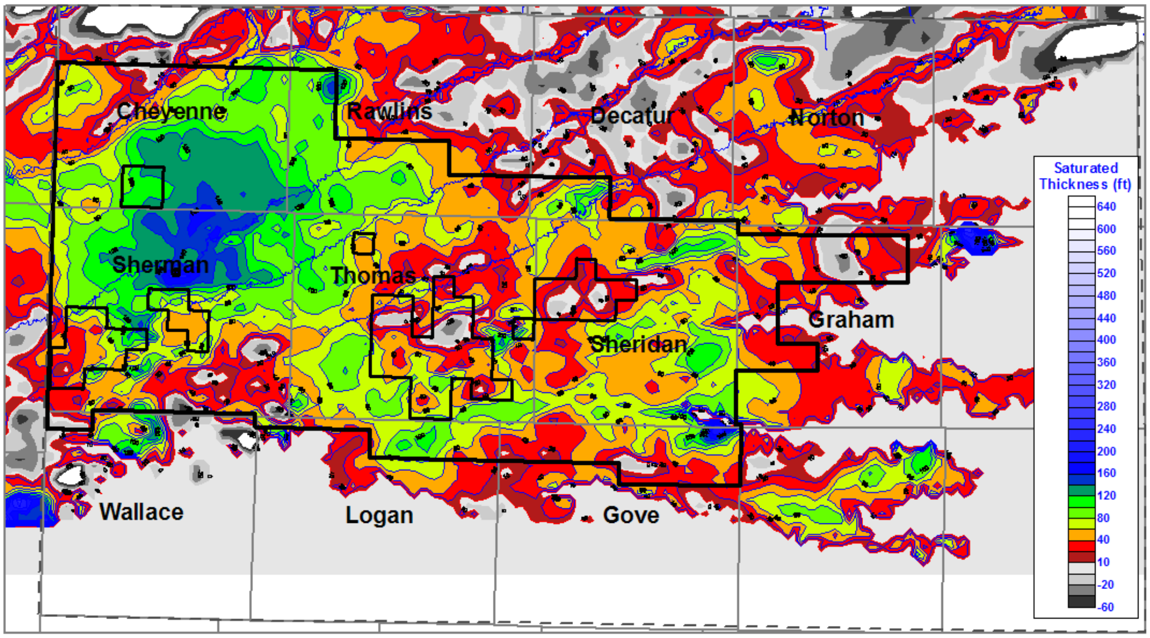

Figure 12: 2055 Estimated Saturated Thickness - Scenario 1.

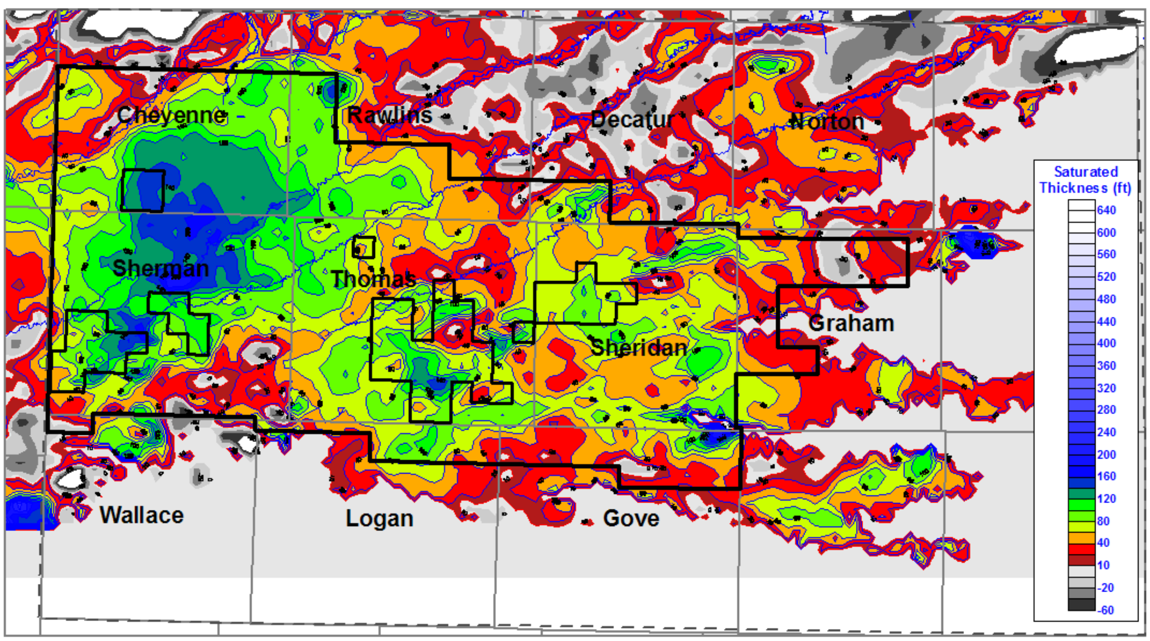

Figure 13: 2055 Estimated Saturated Thickness - Scenario 2.

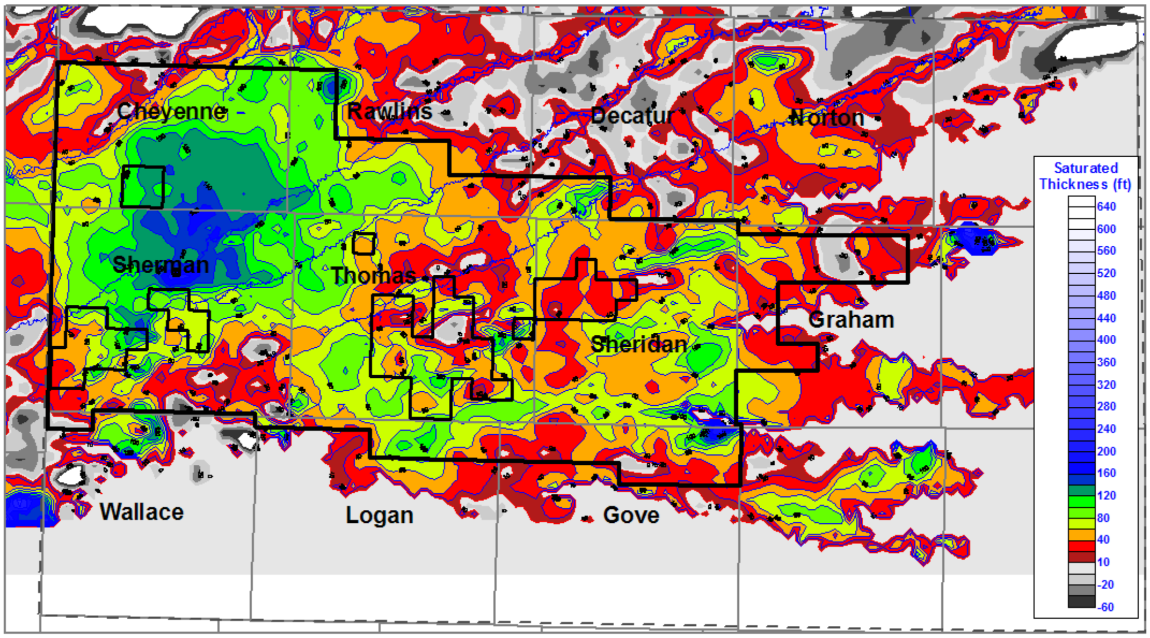

Figure 14: 2055 Estimated Saturated Thickness - Scenario 3.

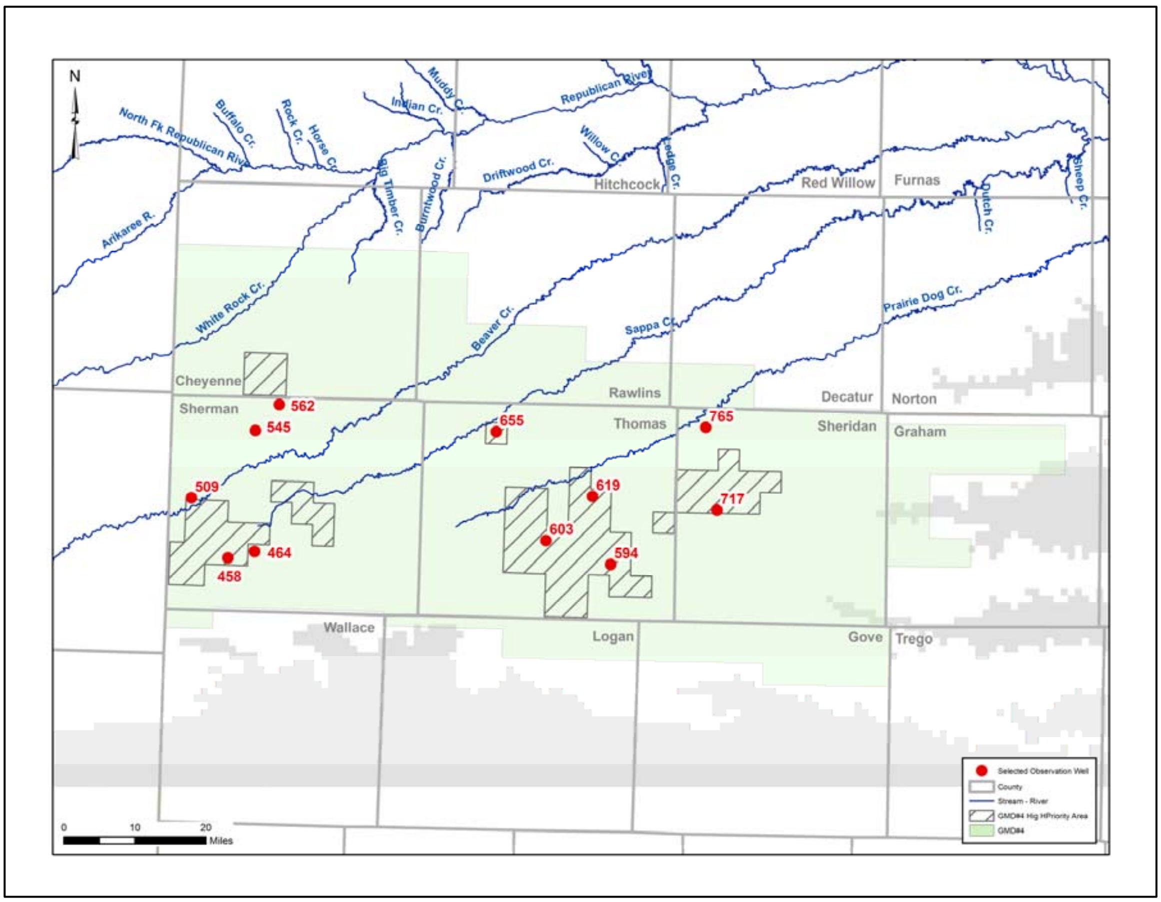

Figure 15: Location of Wells for Selected Hydrographs.

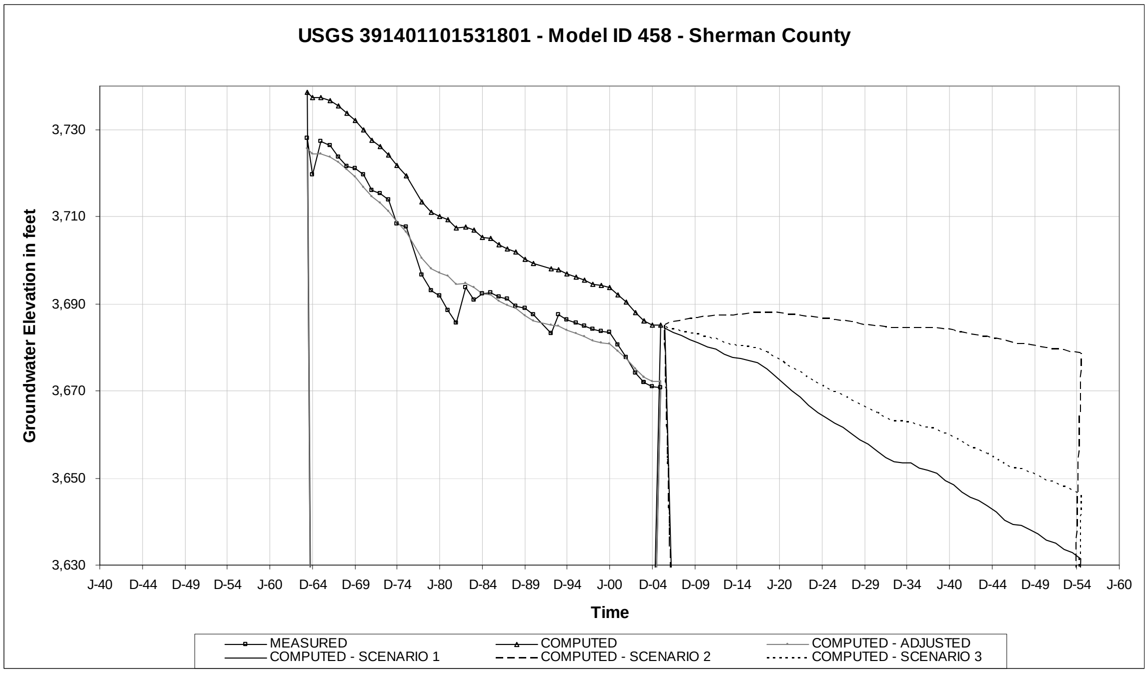

Figure 16a: Hydrograph - USGS 391401101531801 - Model ID 458 - Sherman County.

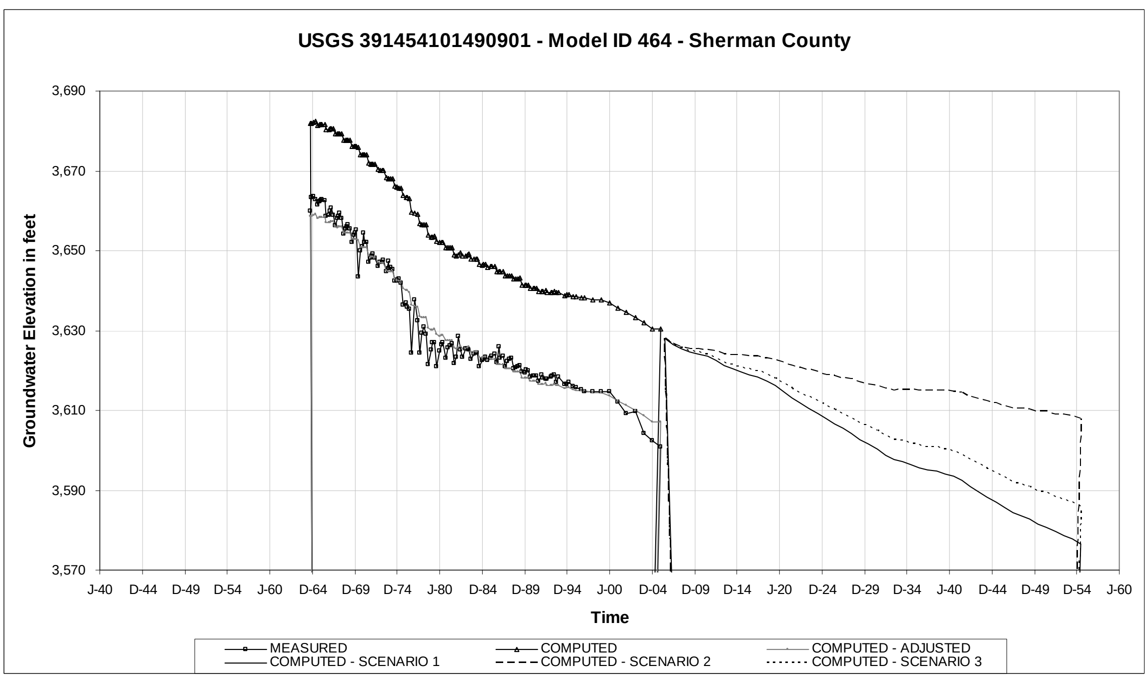

Figure 17b: Hydrograph - USGS 391454101490901 - Model ID 464 - Sherman County.

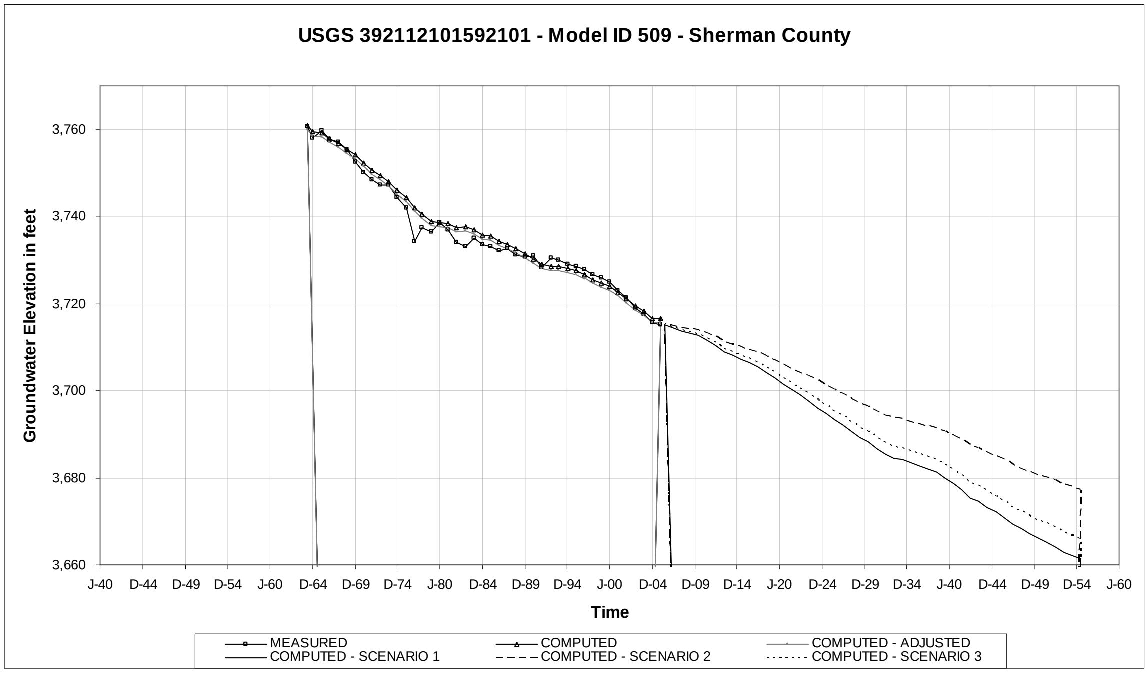

Figure 18c: Hydrograph - USGS 392112101592101 - Model ID 509 - Sherman County.

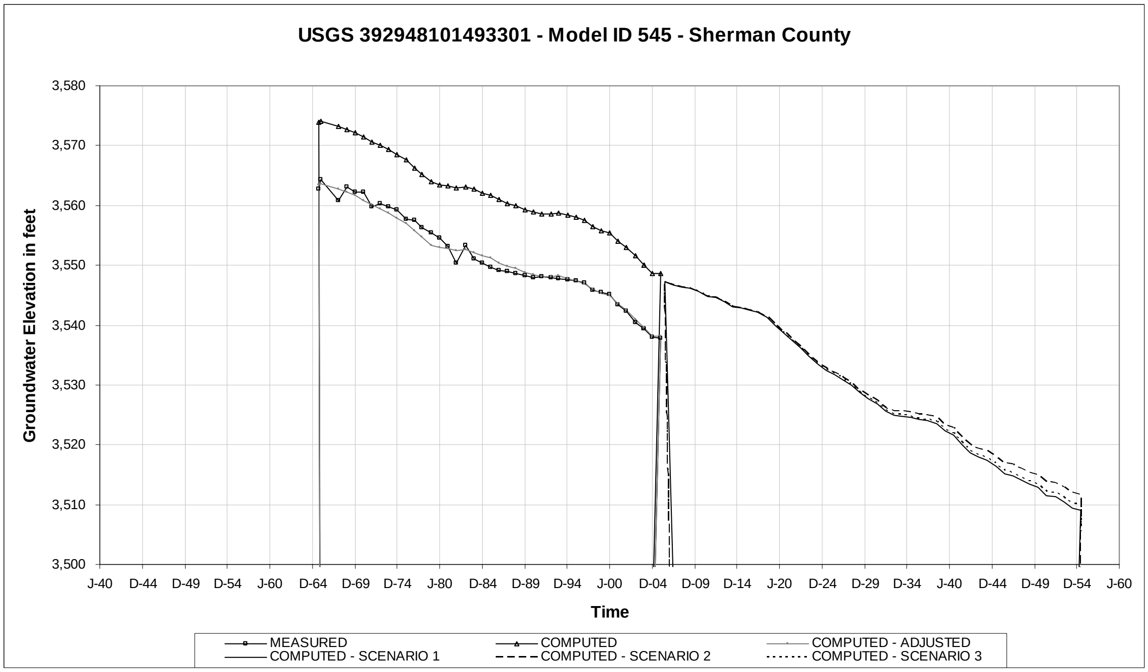

Figure 19d: Hydrograph - USGS 392948101493301 - Model ID 545 - Sherman County.

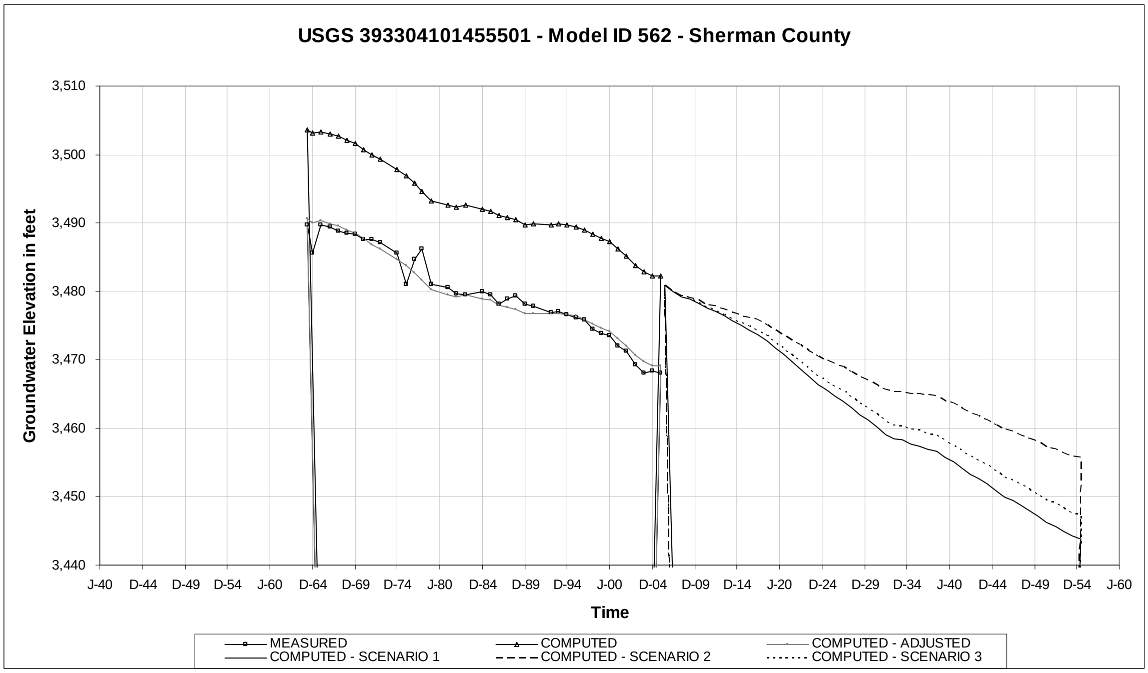

Figure 20e: Hydrograph - USGS 393304101455501 - Model ID 562 - Sherman County.

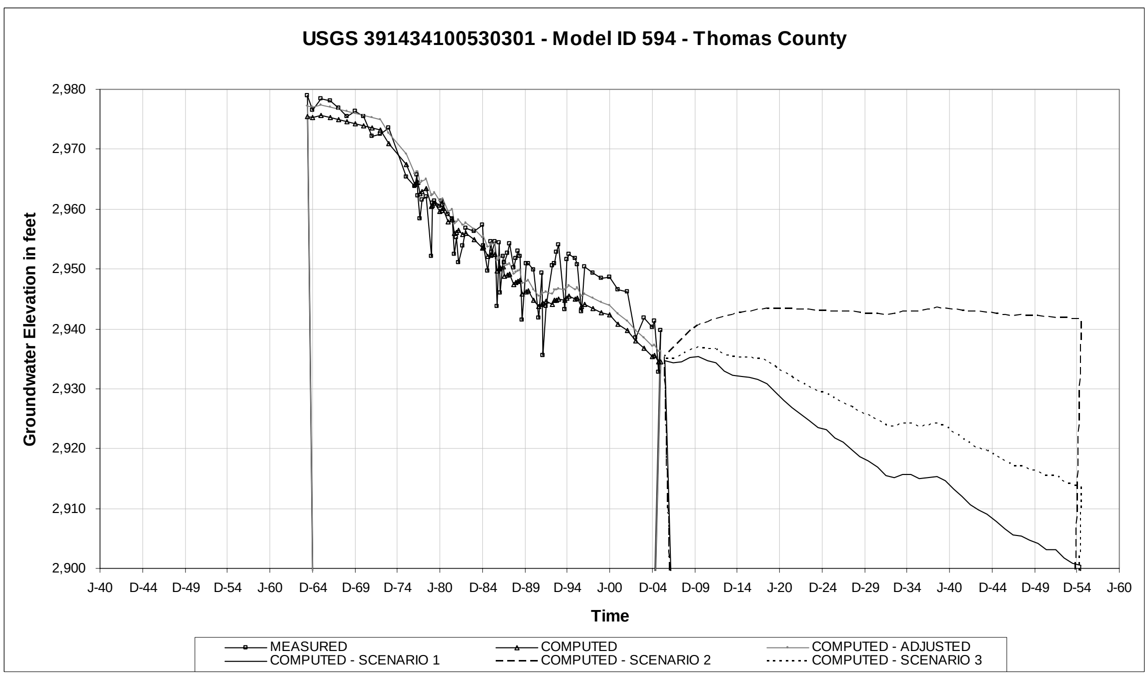

Figure 21f: Hydrograph - USGS 391434100530301 - Model ID 594 - Thomas County.

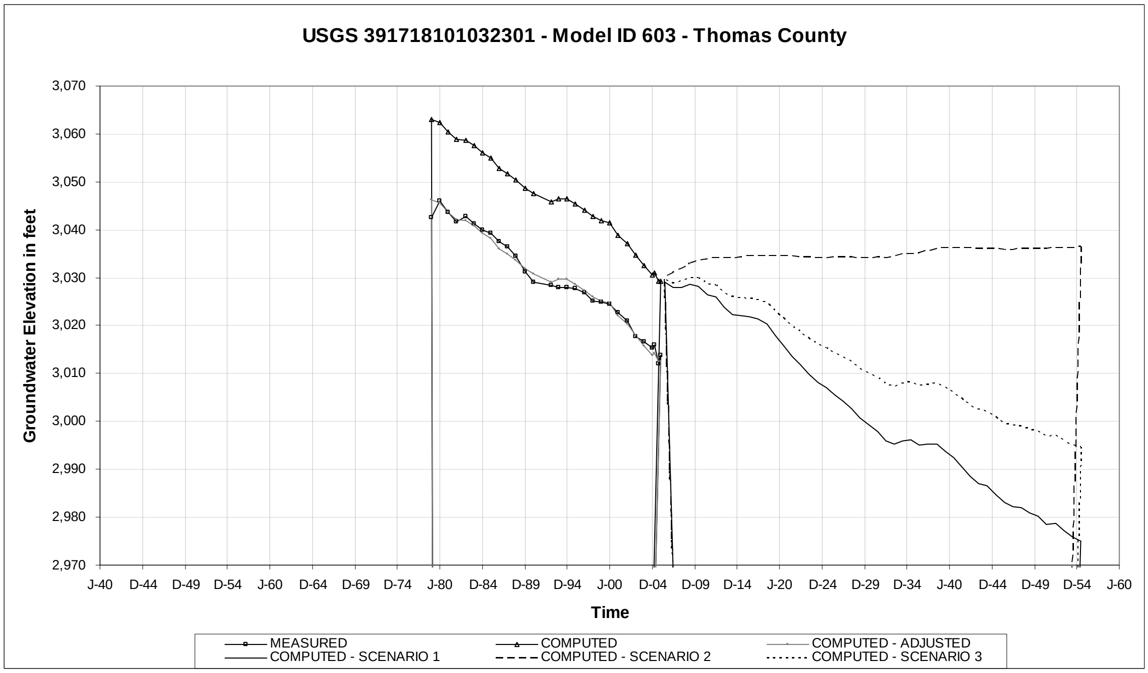

Figure 22g: Hydrograph - USGS 391718101032301 - Model ID 603 - Thomas County.

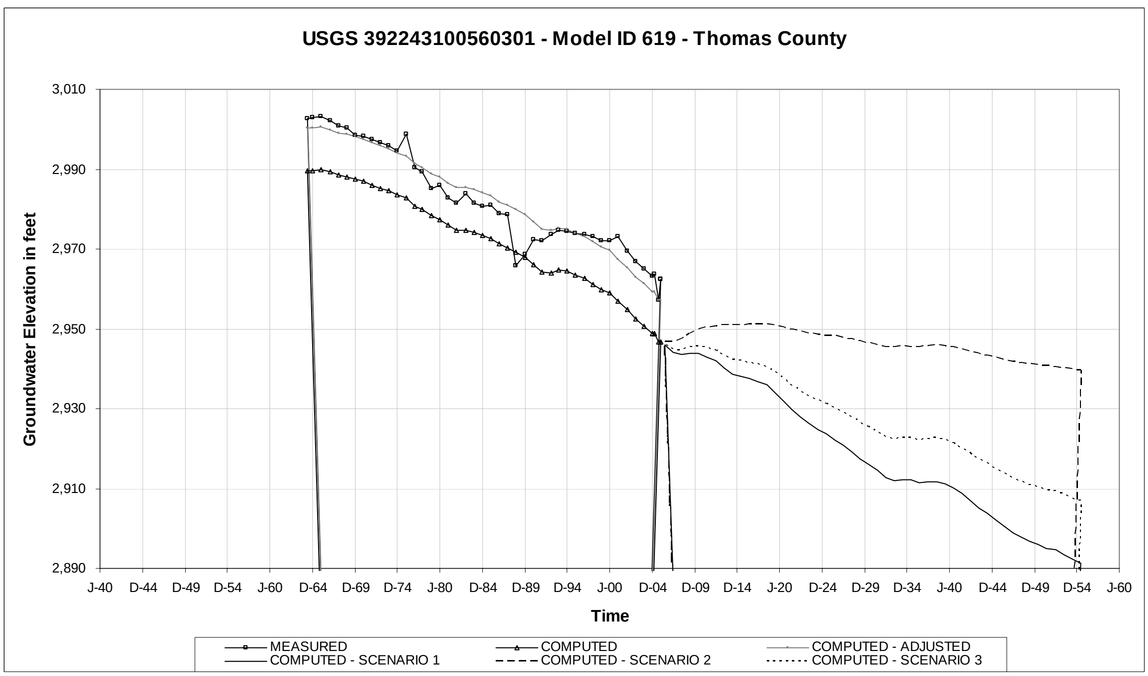

Figure 23h: Hydrograph - USGS 392243100560301 - Model ID 619 - Thomas County.

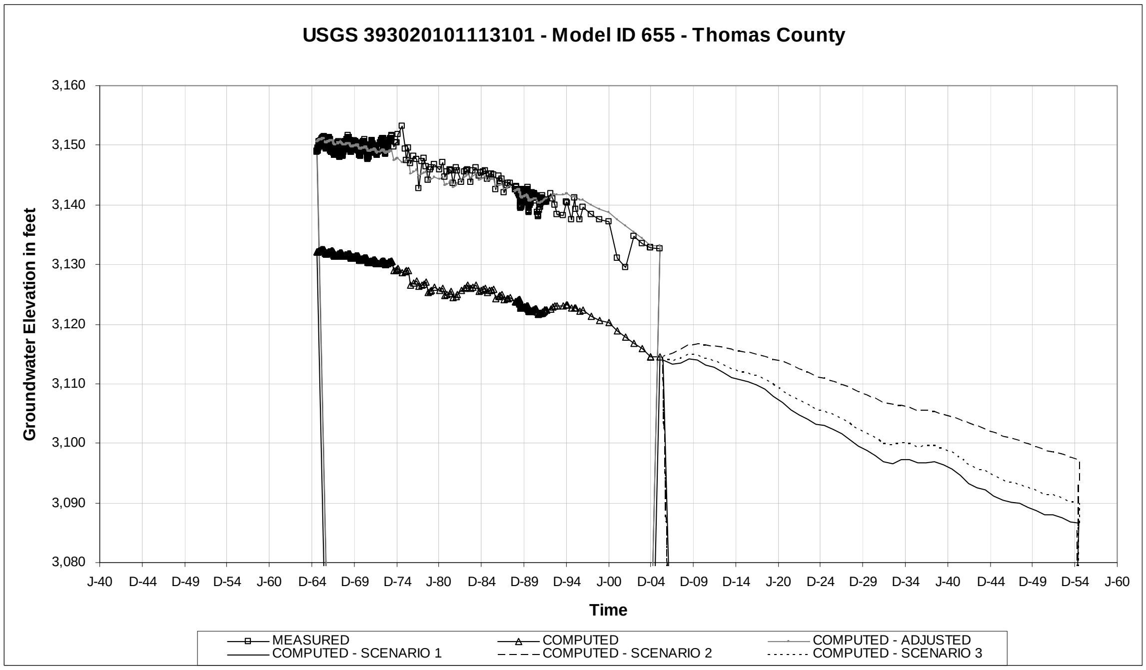

Figure 24i: Hydrograph - USGS 393020101113101 - Model ID 655 - Thomas County.

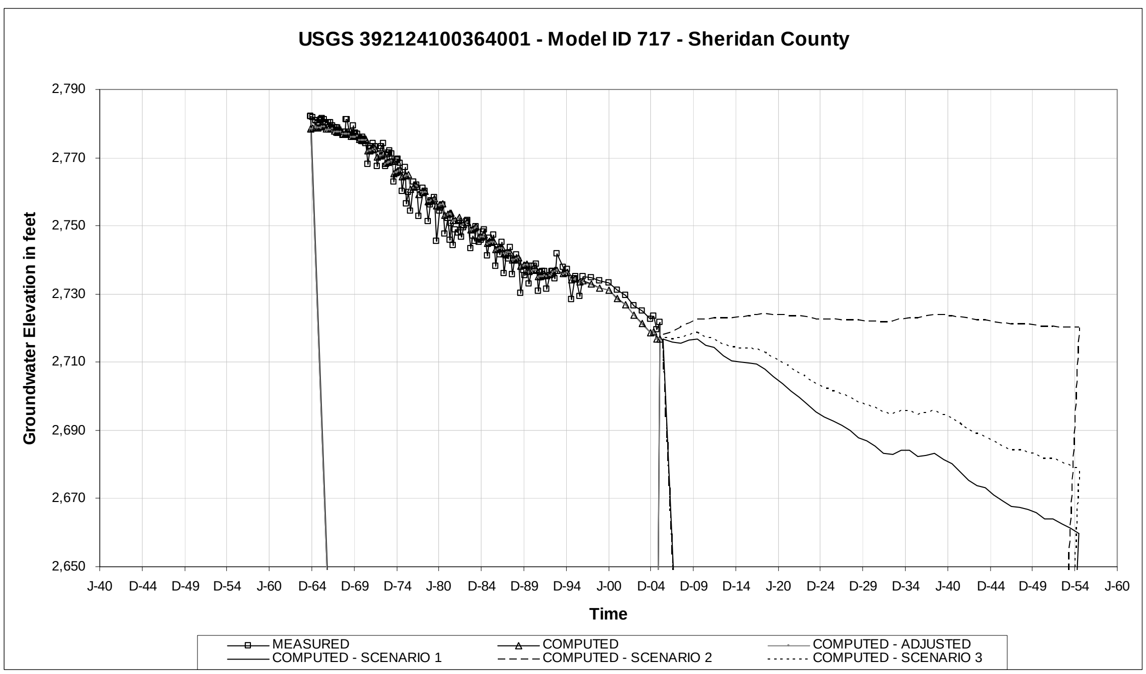

Figure 25j: Hydrograph - USGS 392124100364001 - Model ID 717 - Sheridan County.

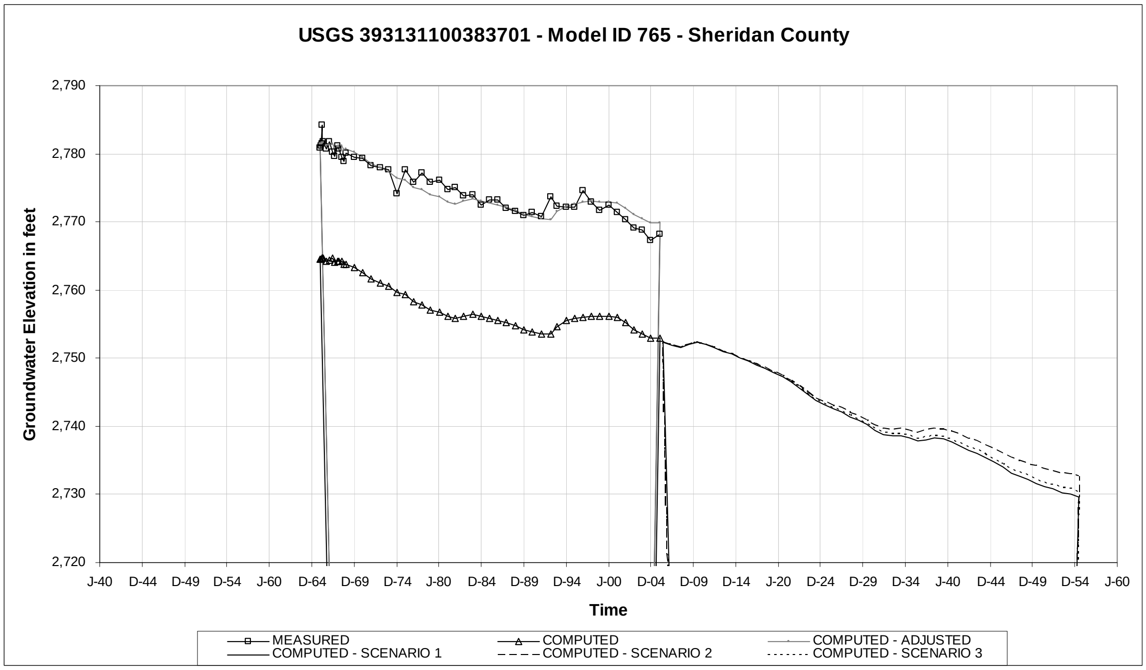

Figure 26k: Hydrograph - USGS 393131100383701 - Model ID 765 - Sheridan County.

Table 1: Precipitation Stations and Locations.

Station ID	Station Name	Easting	Northing
C050109	Akron 4 E	480,549	14,607,776
C051121	Burlington	710,588	14,263,754
C051564	Cheyenne Wells	686,112	14,112,695
C054082	Holyoke	724,056	14,755,644
C054413	Julesburg	738,747	14,901,009
C059243	Wray	749,903	14,572,326
C141179	Burr Oak 1 N	1,831,189	14,483,074
C143527	Hays 1 S	1,545,538	14,113,573
C145363	Minneapolis	2,009,059	14,213,125
C145856	Norton 9 SSE	1,406,128	14,430,033
C146374	Phillipsburg 1 SSE	1,546,746	14,441,255
C148495	Wakeeney	1,390,477	14,170,432
C250640	Beaver City	1,407,487	14,575,688
C250810	Bertrand	1,464,389	14,714,821
C252065	Culbertson	1,128,713	14,616,300
C252690	Elwood 8 S	1,394,783	14,703,279
C253365	Gothenburg	1,322,774	14,868,020
C253735	Hebron	2,036,109	14,595,960
C253910	Holdredge	1,538,380	14,684,054
C254110	Imperial	903,844	14,725,259
C255090	Madrid	935,167	14,845,850
C255310	McCook	1,188,038	14,603,001
C255565	Minden	1,654,313	14,714,193
C256480	Palisade	1,050,642	14,660,550
C256585	Paxton	993,099	14,941,433
C257070	Red Cloud	1,775,580	14,562,825
C258255	Stratton	1,016,296	14,588,511
C258320	Superior	1,901,742	14,533,481
C258735	Upland	1,677,566	14,653,524
C259020	Wauneta 3 NW	968,206	14,705,184
C439	ATWOOD 2 SW	1,059,912	14,459,922
C441	ATWOOD 8 SSE	1,087,070	14,416,792
C836	BIRD CITY 10 S	926,950	14,396,538
C1699	COLBY 1 SW	1,056,422	14,308,180
C2213	DRESDEN	1,241,441	14,389,622
C3153	GOODLAND RENNER FLD	881,986	14,306,720
C3837	HOXIE	1,230,500	14,292,660
C5127	MC DONALD	975,478	14,455,928
C5355	MINGO 5 E	1,112,064	14,264,491
C5888	OAKLEY 4 W	1,091,918	14,204,187
C5906	OBERLIN	1,214,510	14,462,910
C6787	REXFORD 1 SW	1,146,390	14,330,575
C7093	SAINT FRANCIS	853,534	14,453,398
C7095	ST FRANCIS 8 NW	821,326	14,472,656
C8988	WINONA	1,006,349	14,187,933

Table 2: Power Function Curve Parameters.

Soil Type	Land Use	Power, n	Threshold, P_0	Coefficient, A
Coarse	Non-Irrigated	1.35	9	0.120
	Irrigated	1.50	4	0.060
Medium	Non-Irrigated	1.20	15	0.175
	Irrigated	1.70	6	0.025
Fine	Non-Irrigated	1.20	16	0.055
	Irrigated	1.45	2	0.020
AlluvX	Non-Irrigated	1.60	15	0.090
	Irrigated	1.60	15	0.097
AlluvY	Non-Irrigated	1.65	9	0.024
	Irrigated	1.55	11	0.045

Table 3: Summary Statistics of Water Level Change Calibration.

Period	1964-2006	1970-2006	1970-1980	1980-1990	1990-2000	2000-2006	1990-2006
Average drawdown measured	-16.9	-14.4	-8.1	-2.9	-0.8	-4.5	-5.6
Average drawdown computed	-16.8	-14.1	-7.4	-3.0	-1.6	-3.7	-5.6
Maximum drawdown measured	-80.2	-75.2	-37.3	-17.8	-14.4	-29.8	-35.9
Minimum drawdown measured	10.8	10.9	19.0	21.1	11.1	7.4	8.9
Range measured drawdown	91.0	86.1	56.2	39.0	25.5	37.2	44.8
Ratio std dev/range	6.7%	7.1%	8.0%	12.5%	12.0%	9.5%	9.6%
Average residual	-0.1	-0.3	-0.6	0.1	0.8	-0.7	0.0
Standard deviation of residuals	6.1	6.1	4.5	4.9	3.1	3.5	4.3
Correlation coefficient	95.3%	93.0%	83.4%	60.6%	72.8%	65.7%	81.6%
Count of measurements	123	187	293	192	237	333	230

Table 4: Groundwater Budget Summaries – Scenarios 1 and 2.

Scenario 1

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	536,732	173,634	2,061,896	172,277	5,706	2,515	1,865	367	10,943	7,463	201,136	374,770	28,859
ET	(57,558)	(47,990)	(294,605)	(17,727)	-	-	-	-	-	-	(17,727)	(65,717)	-
Drains	(6,896)	(68,176)	(16,877)	(4,450)	-	-	-	-	-	-	(4,450)	(72,626)	-
Storage	437,089	(6,631)	326,392	178,734	13,216	4,944	2,889	576	22,066	12,671	235,097	228,465	56,362
Streams	(19,816)	(25,219)	(47,110)	(21,593)	-	-	-	-	-	-	(21,593)	(46,812)	-
Wells	(777,742)	(38,933)	(1,668,270)	(275,819)	(22,965)	(10,739)	(7,141)	(1,039)	(35,611)	(26,174)	(379,488)	(418,421)	(103,669)
Net	111,809	(13,315)	361,425	31,422	(4,043)	(3,280)	(2,387)	(97)	(2,601)	(6,039)	12,974	(341)	(18,448)

**Negative Net is net inflow to area*

Scenario 2

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	536,732	173,634	2,061,896	172,277	1,103	530	333	162	4,186	2,290	180,880	354,514	8,603
ET	(57,558)	(47,991)	(294,609)	(17,739)	-	-	-	-	-	-	(17,739)	(65,731)	-
Drains	(6,896)	(68,177)	(16,877)	(4,450)	-	-	-	-	-	-	(4,450)	(72,627)	-
Storage	435,137	(6,675)	326,391	148,043	3,517	1,168	647	387	994	113	154,869	148,194	6,826
Streams	(19,816)	(25,217)	(47,107)	(21,711)	-	-	-	-	-	-	(21,711)	(46,928)	-
Wells	(777,742)	(38,933)	(1,668,270)	(275,819)	-	(899)	-	-	(13)	(147)	(276,878)	(315,811)	(1,059)
Net	109,857	(13,359)	361,425	600	4,620	799	980	549	5,166	2,255	14,970	1,611	14,370

**Negative Net is net inflow to area*

Scenario 1 minus Scenario 2

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	-	-	-	-	4,603	1,985	1,532	205	6,758	5,173	20,256	20,256	20,256
ET	0	1	3	12	-	-	-	-	-	-	12	14	-
Drains	-	1	-	-	-	-	-	-	-	-	-	1	-
Storage	1,953	44	0	30,691	9,699	3,776	2,242	189	21,072	12,558	80,227	80,271	49,536
Streams	0	(2)	(4)	118	-	-	-	-	-	-	118	116	-
Wells	-	-	-	-	(22,965)	(9,841)	(7,141)	(1,039)	(35,598)	(26,026)	(102,610)	(102,610)	(102,610)
Net	1,953	44	(0)	30,821	(8,663)	(4,080)	(3,367)	(645)	(7,768)	(8,295)	(1,996)	(1,953)	(32,818)

Table 5: Groundwater Budget Summaries – Scenarios 1 and 3.

Scenario 1

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	536,732	173,634	2,061,896	172,277	5,706	2,515	1,865	367	10,943	7,463	201,136	374,770	28,859
ET	(57,558)	(47,990)	(294,605)	(17,727)	-	-	-	-	-	-	(17,727)	(65,717)	-
Drains	(6,896)	(68,176)	(16,877)	(4,450)	-	-	-	-	-	-	(4,450)	(72,626)	-
Storage	437,089	(6,631)	326,392	178,734	13,216	4,944	2,889	576	22,066	12,671	235,097	228,465	56,362
Streams	(19,816)	(25,219)	(47,110)	(21,593)	-	-	-	-	-	-	(21,593)	(46,812)	-
Wells	(777,742)	(38,933)	(1,668,270)	(275,819)	(22,965)	(10,739)	(7,141)	(1,039)	(35,611)	(26,174)	(379,488)	(418,421)	(103,669)
Net	111,809	(13,315)	361,425	31,422	(4,043)	(3,280)	(2,387)	(97)	(2,601)	(6,039)	12,974	(341)	(18,448)

**Negative Net is net inflow to area*

Scenario 3

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	536,732	173,634	2,061,896	172,277	4,324	1,919	1,405	305	8,914	5,910	195,054	368,688	22,777
ET	(57,558)	(47,990)	(294,606)	(17,731)	-	-	-	-	-	-	(17,731)	(65,721)	-
Drains	(6,896)	(68,176)	(16,877)	(4,450)	-	-	-	-	-	-	(4,450)	(72,627)	-
Storage	436,541	(6,643)	326,391	170,179	10,167	3,745	2,187	518	15,550	8,640	210,986	204,343	40,806
Streams	(19,816)	(25,218)	(47,109)	(21,623)	-	-	-	-	-	-	(21,623)	(46,841)	-
Wells	(777,742)	(38,933)	(1,668,270)	(275,819)	(16,075)	(7,787)	(4,999)	(728)	(24,930)	(18,365)	(348,702)	(387,635)	(72,883)
Net	111,261	(13,326)	361,425	22,833	(1,584)	(2,123)	(1,407)	95	(466)	(3,815)	13,533	207	(9,300)

**Negative Net is net inflow to area*

Scenario 1 minus Scenario 3

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	-	-	-	-	1,382	596	460	62	2,029	1,553	6,082	6,082	6,082
ET	0	0	1	3	-	-	-	-	-	-	3	4	-
Drains	-	0	-	-	-	-	-	-	-	-	-	0	-
Storage	548	12	0	8,555	3,049	1,199	702	58	6,517	4,031	24,111	24,123	15,556
Streams	0	(1)	(1)	30	-	-	-	-	-	-	30	29	-
Wells	-	-	-	-	(6,890)	(2,952)	(2,142)	(312)	(10,681)	(7,809)	(30,786)	(30,786)	(30,786)
Net	548	12	(0)	8,589	(2,458)	(1,157)	(981)	(192)	(2,135)	(2,225)	(560)	(548)	(9,148)

Appendix A: Precipitation Stations and Annual Values used in Recalibration.

YEAR	C050109	C051121	C051564	C054082	C054413	C059243	C141179	C143527	C145363	C145856	C146374	C148495	C250640	C250810
1948	7.11	16.45	17.47	12.79	15.07	18.48	20.92	26.19	32.67	19.42	16.56	25.33	13.66	19.04
1949	25.16	19.91	17.53	24.17	18.43	24.47	29.49	23.62	21.59	28.28	28.94	23.64	27.08	25.30
1950	14.99	14.01	12.70	14.11	14.87	16.40	31.59	25.59	27.19	21.73	24.87	19.85	20.95	22.26
1951	16.64	19.97	15.28	23.93	25.62	20.07	38.97	43.34	55.46	31.62	40.38	36.92	25.22	24.59
1952	14.22	14.18	13.69	12.33	19.19	14.39	19.36	13.39	21.77	16.00	19.65	16.51	22.19	16.04
1953	14.05	9.34	12.99	17.01	19.33	13.49	17.53	21.07	24.10	28.48	19.28	21.87	24.07	18.44
1954	9.69	6.40	9.54	18.59	10.45	10.86	30.96	18.56	19.61	17.49	18.09	16.81	14.60	17.73
1955	14.74	12.09	9.45	17.02	17.62	11.88	14.65	21.16	26.06	16.46	17.00	19.20	13.41	18.56
1956	10.65	9.87	6.96	13.18	17.51	10.04	20.70	9.21	16.01	12.48	11.67	13.40	11.46	12.59
1957	17.33	25.49	22.18	16.66	19.77	19.61	27.41	28.33	38.99	26.64	32.14	36.04	28.14	30.27
1958	16.73	26.08	25.22	24.16	23.11	23.00	0.00	31.21	31.54	22.67	24.02	26.46	23.59	17.58
1959	13.08	13.22	17.68	20.93	13.89	14.46	0.00	24.43	28.37	22.19	22.81	23.05	19.73	21.59
1960	11.35	21.10	17.53	15.18	15.31	17.27	0.00	20.47	30.31	25.44	27.45	26.96	25.27	22.93
1961	16.47	18.14	19.96	17.88	18.93	20.30	0.00	28.31	31.46	23.77	29.67	37.15	25.17	19.31
1962	13.70	18.33	15.77	21.74	15.94	28.45	0.00	23.09	26.20	25.05	27.97	20.10	24.97	25.06
1963	14.07	13.20	11.73	14.93	14.80	14.93	0.00	22.17	20.57	21.71	26.65	17.34	22.78	24.94
1964	12.66	8.86	10.89	12.95	12.76	11.77	0.00	19.76	24.99	14.48	17.72	15.16	20.24	15.78
1965	14.73	26.01	18.82	19.61	25.23	21.06	0.00	24.49	23.85	34.43	35.67	35.29	36.06	37.22
1966	14.36	14.58	17.83	22.31	20.26	22.53	0.00	17.14	18.63	19.91	16.81	14.43	23.35	20.26
1967	16.14	15.52	13.43	21.22	15.55	16.29	0.00	23.64	42.22	24.48	23.50	21.75	26.00	25.65
1968	11.98	11.57	9.79	11.57	13.08	15.28	0.00	18.83	22.15	21.42	28.63	20.05	21.00	23.29
1969	11.22	12.47	21.05	15.87	17.55	16.31	0.00	25.12	25.90	25.24	32.94	25.12	26.74	30.67
1970	12.21	11.81	17.00	14.54	13.72	15.31	0.00	18.23	25.33	17.86	19.67	25.77	18.53	15.61
1971	12.22	15.68	15.08	21.56	18.77	16.30	0.00	23.75	33.83	23.66	21.94	21.38	27.96	24.19
1972	12.00	14.24	15.12	18.79	15.50	15.58	0.00	22.39	31.38	23.87	20.97	25.97	22.58	19.81
1973	21.43	15.53	16.72	23.13	19.36	24.35	0.00	35.00	47.96	25.67	32.16	30.73	29.83	24.26
1974	11.98	9.72	8.43	13.16	8.83	14.32	0.00	12.24	21.64	17.18	13.79	14.31	13.93	13.75
1975	16.39	13.28	12.43	15.63	21.64	15.93	0.00	22.60	27.57	24.25	22.10	26.95	25.79	24.48
1976	11.72	7.41	12.25	12.71	9.34	11.26	0.00	20.73	24.61	15.22	22.22	18.72	19.44	18.46
1977	12.41	12.72	13.25	21.93	20.53	18.82	0.00	20.28	34.20	22.45	20.34	20.03	24.97	23.92
1978	14.17	13.76	14.64	9.94	11.25	11.96	0.00	17.43	23.95	16.33	20.01	18.44	16.67	18.90
1979	20.10	18.61	16.94	19.35	18.28	14.82	0.00	23.62	30.54	26.14	27.33	24.60	24.20	31.57
1980	15.51	17.95	16.80	20.69	13.22	21.40	0.00	18.03	18.10	16.05	18.29	19.37	22.72	20.11
1981	18.84	17.27	18.99	24.36	20.29	20.85	0.00	23.91	34.85	25.34	23.75	19.39	30.15	25.74
1982	16.93	17.94	17.34	25.06	17.35	25.44	0.00	20.68	33.43	21.08	23.81	22.02	24.79	25.65
1983	17.52	17.40	15.69	17.55	15.72	16.22	0.00	15.98	0.00	21.36	25.68	18.08	26.47	23.95
1984	18.34	12.42	12.48	16.51	12.69	13.53	0.00	25.14	0.00	21.73	21.46	28.25	26.68	26.10
1985	18.21	18.93	16.92	16.76	15.14	17.29	0.00	21.63	0.00	23.37	19.25	19.74	27.47	31.31
1986	13.45	12.38	14.21	14.46	14.58	15.04	0.00	23.32	0.00	21.62	24.15	24.11	19.68	20.94
1987	19.75	18.58	17.51	19.35	23.11	15.08	0.00	27.05	34.99	25.37	27.50	24.36	24.70	29.04
1988	17.60	14.11	16.46	19.42	19.89	15.73	0.00	14.28	17.17	16.41	17.64	15.84	20.98	17.71
1989	13.61	14.16	20.93	16.51	13.18	15.20	0.00	17.58	19.41	17.12	18.49	18.85	14.74	20.83
1990	19.40	13.71	16.04	14.40	18.20	18.75	0.00	24.21	29.32	18.15	28.26	24.71	20.49	21.32
1991	14.53	17.20	17.41	19.30	18.20	24.15	0.00	15.99	23.34	19.11	22.48	18.26	20.53	17.20
1992	16.30	19.58	18.68	17.08	24.35	19.99	0.00	28.53	38.79	30.70	25.32	27.43	22.15	25.47
1993	14.28	16.38	14.19	19.17	16.79	18.53	0.00	37.99	53.15	29.84	39.12	37.23	35.76	34.93
1994	13.55	17.66	17.11	13.02	13.21	19.29	0.00	16.24	22.83	26.65	0.00	17.74	21.17	20.45
1995	24.07	23.09	21.78	19.20	15.19	20.07	0.00	18.47	32.59	25.53	0.00	30.80	24.03	23.25
1996	19.38	18.30	16.71	28.41	24.51	19.87	27.90	31.78	33.31	30.49	0.00	30.55	35.62	34.25
1997	13.47	15.12	16.33	12.30	18.64	16.41	26.50	25.33	36.84	25.32	0.00	30.62	21.78	24.19
1998	13.30	23.86	18.22	18.56	17.03	14.22	28.49	25.41	39.35	21.58	0.00	29.95	21.83	23.36
1999	21.07	25.67	19.94	22.07	18.97	19.91	18.25	23.57	32.43	22.80	0.00	25.66	23.12	27.10
2000	13.34	16.02	11.26	10.61	13.47	15.16	14.97	19.85	25.01	21.25	0.00	24.08	22.02	17.95
2001	16.84	12.40	14.60	21.43	18.33	14.93	33.80	29.11	30.50	22.66	23.16	29.11	25.82	25.46
2002	9.38	9.06	11.25	13.15	12.05	11.79	21.03	17.43	21.65	8.70	12.82	14.33	13.94	13.71
2003	17.01	16.11	13.48	12.58	14.09	11.74	22.03	23.60	24.89	16.63	18.88	17.22	20.95	23.37
2004	15.27	16.80	24.06	22.80	16.18	18.07	27.32	24.09	31.58	18.49	20.49	23.91	24.07	22.15
2005	17.77	15.83	18.53	15.67	14.54	21.02	28.29	23.35	29.29	28.60	29.73	24.53	20.69	23.63

YEAR	C252065	C252690	C253365	C253735	C253910	C254110	C255090	C255310	C255565	C256480	C256585	C257070	C258255
1948	20.99	18.92	20.98	28.97	20.68	15.90	20.39	20.97	19.14	19.02	13.48	20.68	18.29
1949	21.77	23.02	25.60	38.23	25.97	23.73	24.60	24.71	26.59	27.75	19.52	29.07	23.25
1950	19.00	20.73	21.73	30.39	29.48	16.66	17.10	21.48	32.04	15.47	24.26	26.20	17.83
1951	23.82	24.87	29.32	40.45	27.01	25.70	31.12	25.11	35.25	30.69	28.06	37.99	26.98
1952	17.51	15.47	12.84	24.22	21.60	15.19	16.34	18.53	18.25	14.70	14.75	23.80	15.02
1953	19.97	19.73	14.41	26.98	23.96	16.67	17.03	19.93	20.25	15.38	15.77	22.80	15.77
1954	14.10	15.33	16.60	22.28	19.63	14.04	12.63	10.08	20.15	10.33	11.16	21.32	11.13
1955	13.71	15.03	13.00	19.19	19.66	15.11	16.06	14.11	18.06	14.88	14.19	22.35	13.44
1956	11.28	12.74	15.25	16.89	13.22	17.10	14.79	11.00	15.08	12.21	12.87	16.57	12.65
1957	24.29	25.35	26.67	31.76	32.79	21.98	22.81	25.94	31.53	20.76	24.40	33.40	22.15
1958	21.96	18.52	22.14	32.27	20.98	21.76	26.05	20.99	25.24	20.39	25.27	26.25	20.58
1959	22.20	18.51	24.70	30.83	24.24	18.71	19.56	22.83	29.90	20.40	15.36	24.14	20.23
1960	19.91	21.93	19.07	31.84	27.18	17.69	16.20	17.94	33.07	19.58	15.22	27.70	22.50
1961	17.44	20.42	20.23	33.92	28.03	17.11	18.47	18.76	26.20	18.83	17.57	26.14	18.79
1962	26.86	28.28	30.78	28.15	29.42	26.85	26.91	24.33	28.25	26.85	25.61	26.72	31.29
1963	15.99	20.20	21.86	28.10	19.38	18.28	22.52	18.36	15.88	15.52	17.62	25.37	19.49
1964	18.34	16.64	22.55	25.92	18.88	14.36	13.84	16.39	18.92	14.06	17.10	19.13	16.53
1965	29.07	34.03	30.02	28.07	36.85	27.18	25.08	27.79	39.35	25.53	27.93	38.14	27.72
1966	20.48	18.92	18.92	17.74	18.27	18.04	17.14	16.49	16.47	21.26	16.29	16.75	19.54
1967	21.24	24.95	20.67	23.12	26.48	22.05	15.92	20.55	29.45	19.97	17.82	22.90	22.37
1968	22.09	17.16	18.85	31.89	26.25	10.43	15.64	17.46	26.08	14.52	12.00	26.31	16.45
1969	25.04	33.45	21.12	30.05	32.64	17.35	19.27	21.14	26.56	21.87	16.67	31.42	24.73
1970	14.88	13.58	16.80	26.42	21.21	14.03	12.76	9.91	18.96	15.55	13.92	23.98	19.98
1971	21.94	22.05	25.39	28.10	26.71	25.77	26.35	22.86	22.08	22.77	21.48	27.66	29.96
1972	19.61	18.29	18.72	28.98	27.05	20.47	18.48	18.80	26.25	21.19	17.98	29.13	23.92
1973	26.15	22.30	25.16	42.51	34.25	23.29	22.64	29.46	31.75	28.94	17.52	40.36	29.36
1974	17.11	13.69	15.05	14.80	17.33	15.26	13.63	17.95	12.62	18.75	13.37	15.68	18.12
1975	21.69	27.38	20.32	31.64	23.23	19.42	18.11	23.31	23.50	22.35	18.65	24.51	16.40
1976	18.36	19.41	20.73	20.78	17.76	13.19	14.42	15.83	15.33	14.95	13.79	19.22	12.74
1977	26.34	24.52	28.37	38.02	24.30	19.01	21.67	26.50	29.38	25.17	23.69	34.81	21.56
1978	14.26	21.11	23.17	26.65	22.09	17.52	12.96	14.98	19.59	18.64	11.29	26.16	14.75
1979	23.21	29.73	21.16	27.26	30.09	16.89	21.90	25.92	31.32	24.27	18.24	33.27	21.07
1980	17.65	19.12	14.21	21.64	20.74	18.81	16.26	20.01	21.15	17.42	10.36	18.82	17.78
1981	26.15	24.61	29.78	30.65	27.60	25.64	21.84	27.26	32.73	28.33	21.03	30.57	26.78
1982	26.49	26.02	21.01	32.14	23.18	25.15	25.29	20.32	29.98	29.44	17.21	28.54	24.78
1983	19.92	20.84	20.32	35.14	27.09	17.99	16.20	17.65	27.41	16.25	18.33	28.08	18.89
1984	24.71	24.15	27.24	32.68	26.93	17.85	19.76	24.50	25.01	23.83	19.28	21.41	24.40
1985	21.40	27.44	23.01	32.02	26.99	17.32	15.76	24.95	30.09	19.40	18.42	30.83	18.88
1986	18.29	21.80	20.37	38.13	23.81	19.57	18.01	21.57	29.21	18.67	16.23	25.44	16.38
1987	21.46	26.72	26.39	36.32	33.58	21.67	24.17	21.35	28.91	22.52	21.69	29.43	22.36
1988	20.50	21.45	25.77	17.97	22.97	19.59	19.11	19.96	19.44	27.79	20.34	17.49	24.63
1989	19.86	20.88	18.55	23.04	22.64	17.44	17.85	17.07	23.83	22.05	16.25	23.36	19.21
1990	16.41	22.50	17.70	29.39	19.02	23.35	20.39	18.67	17.28	17.73	14.88	30.15	16.16
1991	22.48	21.21	22.96	26.61	21.19	21.54	22.53	22.38	17.07	21.86	17.55	20.47	22.27
1992	24.76	21.72	21.67	42.77	27.52	17.05	19.52	22.08	22.84	26.21	18.81	26.57	21.77
1993	26.46	35.42	30.84	45.27	46.38	30.04	26.21	27.45	41.89	28.84	28.02	36.81	27.38
1994	23.04	24.16	23.10	25.39	24.34	20.13	21.58	20.17	27.70	19.41	15.85	20.03	18.00
1995	21.79	24.06	21.08	26.86	24.71	21.26	27.25	23.21	24.01	21.49	19.58	28.06	17.74
1996	28.12	25.73	25.04	31.62	40.56	24.89	23.24	23.59	29.14	26.14	23.82	29.23	25.09
1997	20.73	17.00	21.11	31.42	22.28	18.52	26.60	22.54	24.96	15.05	20.33	26.09	17.90
1998	15.49	17.41	18.56	29.05	26.39	16.17	21.89	15.27	24.71	16.27	26.09	23.47	15.31
1999	19.90	26.72	23.15	23.46	26.63	21.53	25.45	24.60	26.20	21.45	26.13	23.00	21.56
2000	19.70	21.62	19.47	22.05	22.90	17.93	16.82	22.26	26.35	15.07	18.97	23.91	15.65
2001	21.80	26.31	22.05	32.75	26.96	17.51	24.84	19.27	21.97	17.40	22.26	28.05	15.92
2002	12.32	10.99	14.24	28.69	16.03	8.22	10.85	10.87	16.67	9.90	12.57	19.45	9.27
2003	20.99	16.65	19.73	36.36	20.52	15.11	16.62	22.34	18.90	15.84	16.03	21.37	15.08
2004	28.59	24.60	20.95	30.65	24.74	20.71	21.79	24.11	22.49	22.25	24.52	26.23	22.78
2005	22.69	21.34	19.83	27.90	22.49	18.19	0.32	24.89	20.25	22.22	19.21	23.09	18.04

YEAR	C258320	C258735	C259020	C439	C441	C836	C1699	C2213	C3153	C3837	C5127	C5355	C5888	C5906	C6787	C7093	C7095	C8988
1948	20.06	19.65	19.26	20.38	16.32	15.81	16.37	5.79	3.96	18.61	20.38	6.14	7.77	19.74	16.37	22.06	23.54	5.71
1949	30.85	26.24	27.30	24.92	22.15	25.04	16.37	28.26	21.54	26.94	24.92	26.67	25.94	22.69	16.37	30.99	27.94	23.24
1950	27.05	21.97	15.73	20.06	15.57	17.51	15.52	20.17	14.41	26.03	20.06	19.30	20.34	16.34	15.52	19.74	16.66	17.91
1951	38.94	32.06	27.87	24.70	21.84	21.49	20.19	29.48	18.50	28.23	24.70	26.26	26.63	20.97	20.08	21.54	18.35	21.97
1952	20.81	16.25	17.26	19.07	16.18	19.28	17.41	21.66	14.97	20.44	19.07	19.45	18.96	16.76	17.35	15.80	13.57	14.97
1953	27.28	19.23	19.10	18.54	16.96	16.66	18.09	22.88	16.00	21.90	18.54	20.06	18.66	19.70	18.07	13.75	13.17	14.13
1954	21.15	18.75	14.31	14.27	15.16	12.64	14.84	18.54	13.00	17.74	13.64	17.32	17.08	15.84	14.84	11.07	9.97	14.23
1955	19.02	20.30	14.03	14.83	15.76	10.54	16.89	17.12	11.52	17.21	11.00	16.17	16.56	14.58	16.89	11.08	9.93	14.79
1956	18.10	14.40	16.35	13.83	14.12	12.12	14.13	14.37	9.87	12.66	11.30	10.89	11.16	12.29	14.13	11.89	12.35	11.67
1957	24.76	28.89	21.94	20.61	19.79	18.40	21.29	24.03	15.05	22.68	17.65	21.25	18.57	17.73	21.55	17.21	17.60	17.11
1958	32.82	26.19	22.35	23.36	20.64	22.30	22.71	24.08	16.12	23.93	20.69	20.00	20.48	19.82	23.60	23.27	21.53	18.83
1959	29.34	23.91	18.00	23.03	19.75	18.87	19.60	21.36	15.70	23.47	18.05	21.67	19.63	19.59	20.08	18.87	17.62	17.06
1960	29.29	22.84	23.34	21.75	19.52	18.86	20.48	20.13	14.47	22.48	18.43	20.82	18.69	19.97	19.74	16.77	17.38	16.44
1961	30.89	26.54	18.70	23.54	18.93	20.34	19.37	21.92	16.93	25.59	21.84	20.73	21.26	20.24	21.28	16.42	18.87	17.64
1962	30.12	31.71	30.42	27.04	22.78	21.20	22.82	25.54	18.73	27.63	25.12	21.51	23.68	22.77	20.07	18.76	20.48	19.39
1963	27.71	24.61	16.75	24.65	20.98	19.38	20.09	21.15	17.48	22.15	22.32	18.40	20.55	21.27	19.87	18.44	19.95	14.08
1964	21.57	18.07	13.06	19.34	17.55	16.16	15.08	17.94	13.31	17.67	17.15	13.81	15.11	18.58	13.75	15.25	14.71	14.44
1965	30.66	34.38	24.61	25.29	25.36	22.20	21.85	27.54	17.39	22.57	24.40	21.90	21.99	27.87	23.86	20.39	21.26	20.30
1966	19.62	16.98	18.88	20.06	19.48	15.70	18.04	22.94	14.18	18.79	20.35	21.14	20.26	22.45	18.68	18.95	18.72	19.58
1967	28.45	22.07	20.72	17.95	16.43	13.67	13.75	18.61	14.94	15.90	18.97	17.01	18.14	19.92	16.62	15.93	16.85	16.15
1968	28.33	26.27	13.94	16.25	15.34	12.04	16.19	19.63	14.08	17.10	17.42	17.22	17.40	20.64	14.93	14.79	14.30	14.78
1969	30.66	31.98	23.12	19.10	16.14	15.90	17.23	21.65	16.88	18.36	17.66	19.88	20.47	20.68	18.06	16.75	15.26	18.53
1970	23.74	21.87	14.87	17.97	16.80	14.75	17.39	21.35	14.89	17.83	17.22	19.16	16.68	19.24	17.63	14.11	14.87	17.19
1971	25.55	22.69	20.45	21.67	20.67	15.17	17.60	22.75	16.31	20.85	19.50	19.72	19.76	21.05	19.12	15.15	16.60	15.85
1972	31.11	27.75	20.26	21.48	18.24	17.65	18.01	21.15	19.21	22.45	21.15	19.96	20.97	20.56	16.81	17.16	16.80	18.48
1973	48.72	30.13	27.10	24.24	21.88	21.52	22.53	26.90	20.64	24.82	25.73	22.13	23.11	24.94	21.39	20.65	19.68	20.25
1974	17.57	14.87	16.17	19.46	18.48	16.54	19.76	20.34	16.27	19.27	24.48	18.80	19.57	20.92	16.42	17.64	17.16	16.05
1975	25.77	21.89	17.92	20.24	21.32	16.80	22.26	22.73	16.24	22.84	21.49	20.43	21.59	23.22	20.95	17.60	16.46	19.04
1976	17.27	20.80	11.83	16.16	16.85	11.99	16.11	17.87	11.95	20.78	14.50	19.88	18.94	19.60	15.98	13.57	12.42	12.00
1977	32.64	30.47	22.28	24.35	22.37	15.63	19.32	27.30	16.50	21.77	18.88	18.73	19.23	22.16	19.91	14.23	14.38	16.85
1978	27.70	23.72	16.44	19.60	16.62	13.62	17.18	20.89	15.94	18.67	19.90	18.19	18.74	18.68	16.24	13.56	13.79	16.88
1979	29.56	34.91	19.78	20.50	20.13	16.59	22.23	23.97	22.44	20.05	20.31	20.48	21.06	24.91	20.30	20.38	19.99	18.84
1980	25.57	20.79	16.27	19.03	17.15	18.05	18.40	19.21	24.12	19.57	21.42	16.71	19.44	22.15	18.07	22.50	22.26	19.20
1981	29.13	31.11	22.64	26.18	23.34	21.19	21.97	22.96	23.28	21.33	27.58	19.00	19.52	22.99	23.42	25.58	24.57	17.89
1982	27.09	30.36	26.94	28.99	28.97	19.67	24.67	22.57	24.98	21.73	27.23	23.36	19.13	24.94	24.35	22.44	22.06	20.07
1983	32.15	30.82	17.07	22.80	26.08	19.53	19.71	20.15	20.74	19.27	22.48	16.96	14.04	26.68	21.86	18.79	19.31	17.31
1984	29.37	25.31	21.19	25.05	25.94	16.65	20.05	20.97	20.62	22.90	21.49	19.45	7.20	26.89	22.66	17.91	19.09	21.76
1985	30.93	28.87	16.82	23.81	21.36	16.63	21.20	20.44	21.28	22.54	21.67	17.96	14.73	26.11	21.94	16.73	18.90	19.71
1986	35.50	20.93	18.58	20.33	18.57	15.55	19.23	20.04	17.92	19.39	18.51	15.40	14.43	22.62	19.03	15.87	17.18	16.91
1987	36.86	35.70	21.14	20.89	19.21	19.56	19.12	22.34	18.65	18.81	22.78	17.01	17.67	23.76	19.11	16.94	18.19	21.26
1988	19.52	21.11	17.53	20.12	17.28	18.77	18.02	19.96	19.97	16.16	22.99	16.08	18.73	22.32	18.07	17.70	19.58	19.24
1989	21.45	20.15	14.61	16.04	14.46	16.48	18.07	17.03	19.06	15.44	20.94	16.97	17.06	19.06	17.28	15.52	17.29	15.27
1990	24.86	23.13	19.12	19.00	19.31	17.15	18.06	19.29	19.14	19.87	21.93	18.00	19.12	19.67	22.75	19.27	20.31	15.12
1991	22.75	21.29	20.65	22.86	20.40	19.15	18.54	20.85	21.57	21.85	22.30	20.01	15.23	23.04	23.47	22.24	25.82	13.98
1992	35.13	26.00	20.17	24.12	24.18	20.09	23.20	25.01	22.78	26.55	24.01	22.54	16.31	23.94	25.51	20.12	23.08	20.02
1993	40.92	37.45	25.23	28.55	25.82	20.02	28.23	30.90	26.05	32.34	23.40	27.11	21.57	28.86	27.50	19.99	20.09	23.45
1994	21.14	22.95	19.01	26.42	24.51	17.66	26.51	28.09	20.21	25.15	22.45	22.54	22.20	26.72	25.64	16.07	17.46	19.70
1995	24.58	24.31	16.12	23.72	22.51	18.83	23.74	22.68	20.04	24.02	23.15	20.62	19.60	20.87	23.93	18.93	19.27	19.74
1996	33.15	31.79	26.04	27.55	20.93	19.04	24.76	26.52	19.37	24.98	23.90	18.79	21.52	22.70	21.67	17.96	20.82	21.40
1997	31.76	24.91	15.80	23.96	18.32	18.44	22.16	23.39	19.05	22.28	20.12	20.06	20.21	19.71	21.51	16.24	18.84	19.98
1998	24.86	19.95	16.79	22.04	19.88	18.85	22.11	21.02	18.51	20.83	20.09	21.13	21.72	18.64	22.53	17.15	19.44	21.16
1999	21.20	22.25	23.11	22.38	20.35	19.91	20.33	21.12	19.53	20.88	20.34	21.27	20.66	21.10	22.04	16.73	18.74	20.89
2000	17.16	28.69	17.12	20.41	18.31	17.43	17.86	18.89	19.07	18.31	19.30	19.45	19.14	18.16	17.62	15.42	17.50	17.82
2001	36.68	24.66	2.52	21.92	19.84	19.20	18.01	22.40	17.84	20.82	20.02	19.65	21.02	19.72	18.37	15.37	15.50	15.94
2002	20.74	17.15	8.62	14.64	14.88	13.81	15.44	17.00	12.91	14.66	14.67	13.69	17.64	15.27	16.19	13.97	11.38	11.93
2003	26.67	21.14	17.23	16.94	14.54	15.04	14.68	15.19	13.00	12.97	14.15	13.09	13.93	15.23	14.76	13.78	10.80	10.51
2004	25.47	25.15	22.50	21.06	18.70	17.70	17.77	19.06	18.06	17.24	18.48	16.46	16.98	20.73	18.00	14.57	15.39	17.71
2005	22.78	24.65	16.81	22.65	23.12	19.71	20.77	21.78	17.49	22.94	20.90	20.22	20.96	24.26	21.67	18.60	20.99	16.37

Table 1: Precipitation Stations and Locations.

Station ID	Station Name	Easting	Northing
C050109	Akron 4 E	480,549	14,607,776
C051121	Burlington	710,588	14,263,754
C051564	Cheyenne Wells	686,112	14,112,695
C054082	Holyoke	724,056	14,755,644
C054413	Julesburg	738,747	14,901,009
C059243	Wray	749,903	14,572,326
C141179	Burr Oak 1 N	1,831,189	14,483,074
C143527	Hays 1 S	1,545,538	14,113,573
C145363	Minneapolis	2,009,059	14,213,125
C145856	Norton 9 SSE	1,406,128	14,430,033
C146374	Phillipsburg 1 SSE	1,546,746	14,441,255
C148495	Wakeeney	1,390,477	14,170,432
C250640	Beaver City	1,407,487	14,575,688
C250810	Bertrand	1,464,389	14,714,821
C252065	Culbertson	1,128,713	14,616,300
C252690	Elwood 8 S	1,394,783	14,703,279
C253365	Gothenburg	1,322,774	14,868,020
C253735	Hebron	2,036,109	14,595,960
C253910	Holdredge	1,538,380	14,684,054
C254110	Imperial	903,844	14,725,259
C255090	Madrid	935,167	14,845,850
C255310	McCook	1,188,038	14,603,001
C255565	Minden	1,654,313	14,714,193
C256480	Palisade	1,050,642	14,660,550
C256585	Paxton	993,099	14,941,433
C257070	Red Cloud	1,775,580	14,562,825
C258255	Stratton	1,016,296	14,588,511
C258320	Superior	1,901,742	14,533,481
C258735	Upland	1,677,566	14,653,524
C259020	Wauneta 3 NW	968,206	14,705,184
C439	ATWOOD 2 SW	1,059,912	14,459,922
C441	ATWOOD 8 SSE	1,087,070	14,416,792
C836	BIRD CITY 10 S	926,950	14,396,538
C1699	COLBY 1 SW	1,056,422	14,308,180
C2213	DRESDEN	1,241,441	14,389,622
C3153	GOODLAND RENNER FLD	881,986	14,306,720
C3837	HOXIE	1,230,500	14,292,660
C5127	MC DONALD	975,478	14,455,928
C5355	MINGO 5 E	1,112,064	14,264,491
C5888	OAKLEY 4 W	1,091,918	14,204,187
C5906	OBERLIN	1,214,510	14,462,910
C6787	REXFORD 1 SW	1,146,390	14,330,575
C7093	SAINT FRANCIS	853,534	14,453,398
C7095	ST FRANCIS 8 NW	821,326	14,472,656
C8988	WINONA	1,006,349	14,187,933

Table 2: Power Function Curve Parameters.

Soil Type	Land Use	Power, n	Threshold, P_0	Coefficient, A
Coarse	Non-Irrigated	1.35	9	0.120
	Irrigated	1.50	4	0.060
Medium	Non-Irrigated	1.20	15	0.175
	Irrigated	1.70	6	0.025
Fine	Non-Irrigated	1.20	16	0.055
	Irrigated	1.45	2	0.020
AlluvX	Non-Irrigated	1.60	15	0.090
	Irrigated	1.60	15	0.097
AlluvY	Non-Irrigated	1.65	9	0.024
	Irrigated	1.55	11	0.045

Table 3: Summary Statistics of Water Level Change Calibration.

Period	1964-2006	1970-2006	1970-1980	1980-1990	1990-2000	2000-2006	1990-2006
Average drawdown measured	-16.9	-14.4	-8.1	-2.9	-0.8	-4.5	-5.6
Average drawdown computed	-16.8	-14.1	-7.4	-3.0	-1.6	-3.7	-5.6
Maximum drawdown measured	-80.2	-75.2	-37.3	-17.8	-14.4	-29.8	-35.9
Minimum drawdown measured	10.8	10.9	19.0	21.1	11.1	7.4	8.9
Range measured drawdown	91.0	86.1	56.2	39.0	25.5	37.2	44.8
Ratio std dev/range	6.7%	7.1%	8.0%	12.5%	12.0%	9.5%	9.6%
Average residual	-0.1	-0.3	-0.6	0.1	0.8	-0.7	0.0
Standard deviation of residuals	6.1	6.1	4.5	4.9	3.1	3.5	4.3
Correlation coefficient	95.3%	93.0%	83.4%	60.6%	72.8%	65.7%	81.6%
Count of measurements	123	187	293	192	237	333	230

Table 4: Groundwater Budget Summaries – Scenarios 1 and 2.

Scenario 1

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	536,732	173,634	2,061,896	172,277	5,706	2,515	1,865	367	10,943	7,463	201,136	374,770	28,859
ET	(57,558)	(47,990)	(294,605)	(17,727)	-	-	-	-	-	-	(17,727)	(65,717)	-
Drains	(6,896)	(68,176)	(16,877)	(4,450)	-	-	-	-	-	-	(4,450)	(72,626)	-
Storage	437,089	(6,631)	326,392	178,734	13,216	4,944	2,889	576	22,066	12,671	235,097	228,465	56,362
Streams	(19,816)	(25,219)	(47,110)	(21,593)	-	-	-	-	-	-	(21,593)	(46,812)	-
Wells	(777,742)	(38,933)	(1,668,270)	(275,819)	(22,965)	(10,739)	(7,141)	(1,039)	(35,611)	(26,174)	(379,488)	(418,421)	(103,669)
Net	111,809	(13,315)	361,425	31,422	(4,043)	(3,280)	(2,387)	(97)	(2,601)	(6,039)	12,974	(341)	(18,448)

Negative Net is net inflow to area

Scenario 2

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	536,732	173,634	2,061,896	172,277	1,103	530	333	162	4,186	2,290	180,880	354,514	8,603
ET	(57,558)	(47,991)	(294,609)	(17,739)	-	-	-	-	-	-	(17,739)	(65,731)	-
Drains	(6,896)	(68,177)	(16,877)	(4,450)	-	-	-	-	-	-	(4,450)	(72,627)	-
Storage	435,137	(6,675)	326,391	148,043	3,517	1,168	647	387	994	113	154,869	148,194	6,826
Streams	(19,816)	(25,217)	(47,107)	(21,711)	-	-	-	-	-	-	(21,711)	(46,928)	-
Wells	(777,742)	(38,933)	(1,668,270)	(275,819)	-	(899)	-	-	(13)	(147)	(276,878)	(315,811)	(1,059)
Net	109,857	(13,359)	361,425	600	4,620	799	980	549	5,166	2,255	14,970	1,611	14,370

Negative Net is net inflow to area

Scenario 1 minus Scenario 2

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	-	-	-	-	4,603	1,985	1,532	205	6,758	5,173	20,256	20,256	20,256
ET	0	1	3	12	-	-	-	-	-	-	12	14	-
Drains	-	1	-	-	-	-	-	-	-	-	-	1	-
Storage	1,953	44	0	30,691	9,699	3,776	2,242	189	21,072	12,558	80,227	80,271	49,536
Streams	0	(2)	(4)	118	-	-	-	-	-	-	118	116	-
Wells	-	-	-	-	(22,965)	(9,841)	(7,141)	(1,039)	(35,598)	(26,026)	(102,610)	(102,610)	(102,610)
Net	1,953	44	(0)	30,821	(8,663)	(4,080)	(3,367)	(645)	(7,768)	(8,295)	(1,996)	(1,953)	(32,818)

Table 5: Groundwater Budget Summaries – Scenarios 1 and 3.

Scenario 1

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	536,732	173,634	2,061,896	172,277	5,706	2,515	1,865	367	10,943	7,463	201,136	374,770	28,859
ET	(57,558)	(47,990)	(294,605)	(17,727)	-	-	-	-	-	-	(17,727)	(65,717)	-
Drains	(6,896)	(68,176)	(16,877)	(4,450)	-	-	-	-	-	-	(4,450)	(72,626)	-
Storage	437,089	(6,631)	326,392	178,734	13,216	4,944	2,889	576	22,066	12,671	235,097	228,465	56,362
Streams	(19,816)	(25,219)	(47,110)	(21,593)	-	-	-	-	-	-	(21,593)	(46,812)	-
Wells	(777,742)	(38,933)	(1,668,270)	(275,819)	(22,965)	(10,739)	(7,141)	(1,039)	(35,611)	(26,174)	(379,488)	(418,421)	(103,669)
Net	111,809	(13,315)	361,425	31,422	(4,043)	(3,280)	(2,387)	(97)	(2,601)	(6,039)	12,974	(341)	(18,448)

**Negative Net is net inflow to area*

Scenario 3

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	536,732	173,634	2,061,896	172,277	4,324	1,919	1,405	305	8,914	5,910	195,054	368,688	22,777
ET	(57,558)	(47,990)	(294,606)	(17,731)	-	-	-	-	-	-	(17,731)	(65,721)	-
Drains	(6,896)	(68,176)	(16,877)	(4,450)	-	-	-	-	-	-	(4,450)	(72,627)	-
Storage	436,541	(6,643)	326,391	170,179	10,167	3,745	2,187	518	15,550	8,640	210,986	204,343	40,806
Streams	(19,816)	(25,218)	(47,109)	(21,623)	-	-	-	-	-	-	(21,623)	(46,841)	-
Wells	(777,742)	(38,933)	(1,668,270)	(275,819)	(16,075)	(7,787)	(4,999)	(728)	(24,930)	(18,365)	(348,702)	(387,635)	(72,883)
Net	111,261	(13,326)	361,425	22,833	(1,584)	(2,123)	(1,407)	95	(466)	(3,815)	13,533	207	(9,300)

**Negative Net is net inflow to area*

Scenario 1 minus Scenario 3

2006 to 2055 Averages

	Colorado	Kansas minus GMD4	Nebraska	GMD4 minus subareas	Subarea 1	Subarea 2	Subarea 3	Subarea 4	Subarea 5	Subarea 6	Total GMD4	Total Kansas	Total Subareas
Recharge	-	-	-	-	1,382	596	460	62	2,029	1,553	6,082	6,082	6,082
ET	0	0	1	3	-	-	-	-	-	-	3	4	-
Drains	-	0	-	-	-	-	-	-	-	-	-	0	-
Storage	548	12	0	8,555	3,049	1,199	702	58	6,517	4,031	24,111	24,123	15,556
Streams	0	(1)	(1)	30	-	-	-	-	-	-	30	29	-
Wells	-	-	-	-	(6,890)	(2,952)	(2,142)	(312)	(10,681)	(7,809)	(30,786)	(30,786)	(30,786)
Net	548	12	(0)	8,589	(2,458)	(1,157)	(981)	(192)	(2,135)	(2,225)	(560)	(548)	(9,148)

Appendix A

Precipitation Stations and Annual Values Used in Recalibration

Year	C050109	C051121	C051564	C054082	C054413	C059243	C141179	C143527	C145363	C145856	C146374	C148495	C250640	C250810
1948	7.11	16.45	17.47	12.79	15.07	18.48	20.92	26.19	32.67	19.42	16.56	25.33	13.66	19.04
1949	25.16	19.91	17.53	24.17	18.43	24.47	29.49	23.62	21.59	28.28	28.94	23.64	27.08	25.30
1950	14.99	14.01	12.70	14.11	14.87	16.40	31.59	25.59	27.19	21.73	24.87	19.85	20.95	22.26
1951	16.64	19.97	15.28	23.93	25.62	20.07	38.97	43.34	55.46	31.62	40.38	36.92	25.22	24.59
1952	14.22	14.18	13.69	12.33	19.19	14.39	19.36	13.39	21.77	16.00	19.65	16.51	22.19	16.04
1953	14.05	9.34	12.99	17.01	19.33	13.49	17.53	21.07	24.10	28.48	19.28	21.87	24.07	18.44
1954	9.69	6.40	9.54	18.59	10.45	10.86	30.96	18.56	19.61	17.49	18.09	16.81	14.60	17.73
1955	14.74	12.09	9.45	17.02	17.62	11.88	14.65	21.16	26.06	16.46	17.00	19.20	13.41	18.56
1956	10.65	9.87	6.96	13.18	17.51	10.04	20.70	9.21	16.01	12.48	11.67	13.40	11.46	12.59
1957	17.33	25.49	22.18	16.66	19.77	19.61	27.41	28.33	38.99	26.64	32.14	36.04	28.14	30.27
1958	16.73	26.08	25.22	24.16	23.11	23.00	0.00	31.21	31.54	22.67	24.02	26.46	23.59	17.58
1959	13.08	13.22	17.68	20.93	13.89	14.46	0.00	24.43	28.37	22.19	22.81	23.05	19.73	21.59
1960	11.35	21.10	17.53	15.18	15.31	17.27	0.00	20.47	30.31	25.44	27.45	26.96	25.27	22.93
1961	16.47	18.14	19.96	17.88	18.93	20.30	0.00	28.31	31.46	23.77	29.67	37.15	25.17	19.31
1962	13.70	18.33	15.77	21.74	15.94	28.45	0.00	23.09	26.20	25.05	27.97	20.10	24.97	25.06
1963	14.07	13.20	11.73	14.93	14.80	14.93	0.00	22.17	20.57	21.71	26.65	17.34	22.78	24.94
1964	12.66	8.86	10.89	12.95	12.76	11.77	0.00	19.76	24.99	14.48	17.72	15.16	20.24	15.78
1965	14.73	26.01	18.82	19.61	25.23	21.06	0.00	24.49	23.85	34.43	35.67	35.29	36.06	37.22
1966	14.36	14.58	17.83	22.31	20.26	22.53	0.00	17.14	18.63	19.91	16.81	14.43	23.35	20.26
1967	16.14	15.52	13.43	21.22	15.55	16.29	0.00	23.64	42.22	24.48	23.50	21.75	26.00	25.65
1968	11.98	11.57	9.79	11.57	13.08	15.28	0.00	18.83	22.15	21.42	28.63	20.05	21.00	23.29
1969	11.22	12.47	21.05	15.87	17.55	16.31	0.00	25.12	25.90	25.24	32.94	25.12	26.74	30.67
1970	12.21	11.81	17.00	14.54	13.72	15.31	0.00	18.23	25.33	17.86	19.67	25.77	18.53	15.61
1971	12.22	15.68	15.08	21.56	18.77	16.30	0.00	23.75	33.83	23.66	21.94	21.38	27.96	24.19
1972	12.00	14.24	15.12	18.79	15.50	15.58	0.00	22.39	31.38	23.87	20.97	25.97	22.58	19.81
1973	21.43	15.53	16.72	23.13	19.36	24.35	0.00	35.00	47.96	25.67	32.16	30.73	29.83	24.26
1974	11.98	9.72	8.43	13.16	8.83	14.32	0.00	12.24	21.64	17.18	13.79	14.31	13.93	13.75
1975	16.39	13.28	12.43	15.63	21.64	15.93	0.00	22.60	27.57	24.25	22.10	26.95	25.79	24.48
1976	11.72	7.41	12.25	12.71	9.34	11.26	0.00	20.73	24.61	15.22	22.22	18.72	19.44	18.46
1977	12.41	12.72	13.25	21.93	20.53	18.82	0.00	20.28	34.20	22.45	20.34	20.03	24.97	23.92
1978	14.17	13.76	14.64	9.94	11.25	11.96	0.00	17.43	23.95	16.33	20.01	18.44	16.67	18.90
1979	20.10	18.61	16.94	19.35	18.28	14.82	0.00	23.62	30.54	26.14	27.33	24.60	24.20	31.57
1980	15.51	17.95	16.80	20.69	13.22	21.40	0.00	18.03	18.10	16.05	18.29	19.37	22.72	20.11
1981	18.84	17.27	18.99	24.36	20.29	20.85	0.00	23.91	34.85	25.34	23.75	19.39	30.15	25.74
1982	16.93	17.94	17.34	25.06	17.35	25.44	0.00	20.68	33.43	21.08	23.81	22.02	24.79	25.65
1983	17.52	17.40	15.69	17.55	15.72	16.22	0.00	15.98	0.00	21.36	25.68	18.08	26.47	23.95
1984	18.34	12.42	12.48	16.51	12.69	13.53	0.00	25.14	0.00	21.73	21.46	28.25	26.68	26.10
1985	18.21	18.93	16.92	16.76	15.14	17.29	0.00	21.63	0.00	23.37	19.25	19.74	27.47	31.31
1986	13.45	12.38	14.21	14.46	14.58	15.04	0.00	23.32	0.00	21.62	24.15	24.11	19.68	20.94
1987	19.75	18.58	17.51	19.35	23.11	15.08	0.00	27.05	34.99	25.37	27.50	24.36	24.70	29.04
1988	17.60	14.11	16.46	19.42	19.89	15.73	0.00	14.28	17.17	16.41	17.64	15.84	20.98	17.71
1989	13.61	14.16	20.93	16.51	13.18	15.20	0.00	17.58	19.41	17.12	18.49	18.85	14.74	20.83
1990	19.40	13.71	16.04	14.40	18.20	18.75	0.00	24.21	29.32	18.15	28.26	24.71	20.49	21.32
1991	14.53	17.20	17.41	19.30	18.20	24.15	0.00	15.99	23.34	19.11	22.48	18.26	20.53	17.20
1992	16.30	19.58	18.68	17.08	24.35	19.99	0.00	28.53	38.79	30.70	25.32	27.43	22.15	25.47
1993	14.28	16.38	14.19	19.17	16.79	18.53	0.00	37.99	53.15	29.84	39.12	37.23	35.76	34.93
1994	13.55	17.66	17.11	13.02	13.21	19.29	0.00	16.24	22.83	26.65	0.00	17.74	21.17	20.45
1995	24.07	23.09	21.78	19.20	15.19	20.07	0.00	18.47	32.59	25.53	0.00	30.80	24.03	23.25
1996	19.38	18.30	16.71	28.41	24.51	19.87	27.90	31.78	33.31	30.49	0.00	30.55	35.62	34.25
1997	13.47	15.12	16.33	12.30	18.64	16.41	26.50	25.33	36.84	25.32	0.00	30.62	21.78	24.19
1998	13.30	23.86	18.22	18.56	17.03	14.22	28.49	25.41	39.35	21.58	0.00	29.95	21.83	23.36
1999	21.07	25.67	19.94	22.07	18.97	19.91	18.25	23.57	32.43	22.80	0.00	25.66	23.12	27.10
2000	13.34	16.02	11.26	10.61	13.47	15.16	14.97	19.85	25.01	21.25	0.00	24.08	22.02	17.95
2001	16.84	12.40	14.60	21.43	18.33	14.93	33.80	29.11	30.50	22.66	23.16	29.11	25.82	25.46
2002	9.38	9.06	11.25	13.15	12.05	11.79	21.03	17.43	21.65	8.70	12.82	14.33	13.94	13.71
2003	17.01	16.11	13.48	12.58	14.09	11.74	22.03	23.60	24.89	16.63	18.88	17.22	20.95	23.37
2004	15.27	16.80	24.06	22.80	16.18	18.07	27.32	24.09	31.58	18.49	20.49	23.91	24.07	22.15
2005	17.77	15.83	18.53	15.67	14.54	21.02	28.29	23.35	29.29	28.60	29.73	24.53	20.69	23.63

Year	C252065	C252690	C253365	C253735	C253910	C254110	C255090	C255310	C255565	C256480	C256585	C257070	C258255	C258320
1948	20.99	18.92	20.98	28.97	20.68	15.90	20.39	20.97	19.14	19.02	13.48	20.68	18.29	20.06
1949	21.77	23.02	25.60	38.23	25.97	23.73	24.60	24.71	26.59	27.75	19.52	29.07	23.25	30.85
1950	19.00	20.73	21.73	30.39	29.48	16.66	17.10	21.48	32.04	15.47	24.26	26.20	17.83	27.05
1951	23.82	24.87	29.32	40.45	27.01	25.70	31.12	25.11	35.25	30.69	28.06	37.99	26.98	38.94
1952	17.51	15.47	12.84	24.22	21.60	15.19	16.34	18.53	18.25	14.70	14.75	23.80	15.02	20.81
1953	19.97	19.73	14.41	26.98	23.96	16.67	17.03	19.93	20.25	15.38	15.77	22.80	15.77	27.28
1954	14.10	15.33	16.60	22.28	19.63	14.04	12.63	10.08	20.15	10.33	11.16	21.32	11.13	21.15
1955	13.71	15.03	13.00	19.19	19.66	15.11	16.06	14.11	18.06	14.88	14.19	22.35	13.44	19.02
1956	11.28	12.74	15.25	16.89	13.22	17.10	14.79	11.00	15.08	12.21	12.87	16.57	12.65	18.10
1957	24.29	25.35	26.67	31.76	32.79	21.98	22.81	25.94	31.53	20.76	24.40	33.40	22.15	24.76
1958	21.96	18.52	22.14	32.27	20.98	21.76	26.05	20.99	25.24	20.39	25.27	26.25	20.58	32.82
1959	22.20	18.51	24.70	30.83	24.24	18.71	19.56	22.83	29.90	20.40	15.36	24.14	20.23	29.34
1960	19.91	21.93	19.07	31.84	27.18	17.69	16.20	17.94	33.07	19.58	15.22	27.70	22.50	29.29
1961	17.44	20.42	20.23	33.92	28.03	17.11	18.47	18.76	26.20	18.83	17.57	26.14	18.79	30.89
1962	26.86	28.28	30.78	28.15	29.42	26.85	26.91	24.33	28.25	26.85	25.61	26.72	31.29	30.12
1963	15.99	20.20	21.86	28.10	19.38	18.28	22.52	18.36	15.88	15.52	17.62	25.37	19.49	27.71
1964	18.34	16.64	22.55	25.92	18.88	14.36	13.84	16.39	18.92	14.06	17.10	19.13	16.53	21.57
1965	29.07	34.03	30.02	28.07	36.85	27.18	25.08	27.79	39.35	25.53	27.93	38.14	27.72	30.66
1966	20.48	18.92	18.92	17.74	18.27	18.04	17.14	16.49	16.47	21.26	16.29	16.75	19.54	19.62
1967	21.24	24.95	20.67	23.12	26.48	22.05	15.92	20.55	29.45	19.97	17.82	22.90	22.37	28.45
1968	22.09	17.16	18.85	31.89	26.25	10.43	15.64	17.46	26.08	14.52	12.00	26.31	16.45	28.33
1969	25.04	33.45	21.12	30.05	32.64	17.35	19.27	21.14	26.56	21.87	16.67	31.42	24.73	30.66
1970	14.88	13.58	16.80	26.42	21.21	14.03	12.76	9.91	18.96	15.55	13.92	23.98	19.98	23.74
1971	21.94	22.05	25.39	28.10	26.71	25.77	26.35	22.86	22.08	22.77	21.48	27.66	29.96	25.55
1972	19.61	18.29	18.72	28.98	27.05	20.47	18.48	18.80	26.25	21.19	17.98	29.13	23.92	31.11
1973	26.15	22.30	25.16	42.51	34.25	23.29	22.64	29.46	31.75	28.94	17.52	40.36	29.36	48.72
1974	17.11	13.69	15.05	14.80	17.33	15.26	13.63	17.95	12.62	18.75	13.37	15.68	18.12	17.57
1975	21.69	27.38	20.32	31.64	23.23	19.42	18.11	23.31	23.50	22.35	18.65	24.51	16.40	25.77
1976	18.36	19.41	20.73	20.78	17.76	13.19	14.42	15.83	15.33	14.95	13.79	19.22	12.74	17.27
1977	26.34	24.52	28.37	38.02	24.30	19.01	21.67	26.50	29.38	25.17	23.69	34.81	21.56	32.64
1978	14.26	21.11	23.17	26.65	22.09	17.52	12.96	14.98	19.59	18.64	11.29	26.16	14.75	27.70
1979	23.21	29.73	21.16	27.26	30.09	16.89	21.90	25.92	31.32	24.27	18.24	33.27	21.07	29.56
1980	17.65	19.12	14.21	21.64	20.74	18.81	16.26	20.01	21.15	17.42	10.36	18.82	17.78	25.57
1981	26.15	24.61	29.78	30.65	27.60	25.64	21.84	27.26	32.73	28.33	21.03	30.57	26.78	29.13
1982	26.49	26.02	21.01	32.14	23.18	25.15	25.29	20.32	29.98	29.44	17.21	28.54	24.78	27.09
1983	19.92	20.84	20.32	35.14	27.09	17.99	16.20	17.65	27.41	16.25	18.33	28.08	18.89	32.15
1984	24.71	24.15	27.24	32.68	26.93	17.85	19.76	24.50	25.01	23.83	19.28	21.41	24.40	29.37
1985	21.40	27.44	23.01	32.02	26.99	17.32	15.76	24.95	30.09	19.40	18.42	30.83	18.88	30.93
1986	18.29	21.80	20.37	38.13	23.81	19.57	18.01	21.57	29.21	18.67	16.23	25.44	16.38	35.50
1987	21.46	26.72	26.39	36.32	33.58	21.67	24.17	21.35	28.91	22.52	21.69	29.43	22.36	36.86
1988	20.50	21.45	25.77	17.97	22.97	19.59	19.11	19.96	19.44	27.79	20.34	17.49	24.63	19.52
1989	19.86	20.88	18.55	23.04	22.64	17.44	17.85	17.07	23.83	22.05	16.25	23.36	19.21	21.45
1990	16.41	22.50	17.70	29.39	19.02	23.35	20.39	18.67	17.28	17.73	14.88	30.15	16.16	24.86
1991	22.48	21.21	22.96	26.61	21.19	21.54	22.53	22.38	17.07	21.86	17.55	20.47	22.27	22.75
1992	24.76	21.72	21.67	42.77	27.52	17.05	19.52	22.08	22.84	26.21	18.81	26.57	21.77	35.13
1993	26.46	35.42	30.84	45.27	46.38	30.04	26.21	27.45	41.89	28.84	28.02	36.81	27.38	40.92
1994	23.04	24.16	23.10	25.39	24.34	20.13	21.58	20.17	27.70	19.41	15.85	20.03	18.00	21.14
1995	21.79	24.06	21.08	26.86	24.71	21.26	27.25	23.21	24.01	21.49	19.58	28.06	17.74	24.58
1996	28.12	25.73	25.04	31.62	40.56	24.89	23.24	23.59	29.14	26.14	23.82	29.23	25.09	33.15
1997	20.73	17.00	21.11	31.42	22.28	18.52	26.60	22.54	24.96	15.05	20.33	26.09	17.90	31.76
1998	15.49	17.41	18.56	29.05	26.39	16.17	21.89	15.27	24.71	16.27	26.09	23.47	15.31	24.86
1999	19.90	26.72	23.15	23.46	26.63	21.53	25.45	24.60	26.20	21.45	26.13	23.00	21.56	21.20
2000	19.70	21.62	19.47	22.05	22.90	17.93	16.82	22.26	26.35	15.07	18.97	23.91	15.65	17.16
2001	21.80	26.31	22.05	32.75	26.96	17.51	24.84	19.27	21.97	17.40	22.26	28.05	15.92	36.68
2002	12.32	10.99	14.24	28.69	16.03	8.22	10.85	10.87	16.67	9.90	12.57	19.45	9.27	20.74
2003	20.99	16.65	19.73	36.36	20.52	15.11	16.62	22.34	18.90	15.84	16.03	21.37	15.08	26.67
2004	28.59	24.60	20.95	30.65	24.74	20.71	21.79	24.11	22.49	22.25	24.52	26.23	22.78	25.47
2005	22.69	21.34	19.83	27.90	22.49	18.19	0.32	24.89	20.25	22.22	19.21	23.09	18.04	22.78

Year	C258735	C259020	C439	C441	C836	C1699	C2213	C3153	C3837	C5127	C5355	C5888	C5906	C6787	C7093	C7095	C8988
1948	19.65	19.26	20.38	16.32	15.81	16.37	5.79	3.96	18.61	20.38	6.14	7.77	19.74	16.37	22.06	23.54	5.71
1949	26.24	27.30	24.92	22.15	25.04	16.37	28.26	21.54	26.94	24.92	26.67	25.94	22.69	16.37	30.99	27.94	23.24
1950	21.97	15.73	20.06	15.57	17.51	15.52	20.17	14.41	26.03	20.06	19.30	20.34	16.34	15.52	19.74	16.66	17.91
1951	32.06	27.87	24.70	21.84	21.49	20.19	29.48	18.50	28.23	24.70	26.26	26.63	20.97	20.08	21.54	18.35	21.97
1952	16.25	17.26	19.07	16.18	19.28	17.41	21.66	14.97	20.44	19.07	19.45	18.96	16.76	17.35	15.80	13.57	14.97
1953	19.23	19.10	18.54	16.96	16.66	18.09	22.88	16.00	21.90	18.54	20.06	18.66	19.70	18.07	13.75	13.17	14.13
1954	18.75	14.31	14.27	15.16	12.64	14.84	18.54	13.00	17.74	13.64	17.32	17.08	15.84	14.84	11.07	9.97	14.23
1955	20.30	14.03	14.83	15.76	10.54	16.89	17.12	11.52	17.21	11.00	16.17	16.56	14.58	16.89	11.08	9.93	14.79
1956	14.40	16.35	13.83	14.12	12.12	14.13	14.37	9.87	12.66	11.30	10.89	11.16	12.29	14.13	11.89	12.35	11.67
1957	28.89	21.94	20.61	19.79	18.40	21.29	24.03	15.05	22.68	17.65	21.25	18.57	17.73	21.55	17.21	17.60	17.11
1958	26.19	22.35	23.36	20.64	22.30	22.71	24.08	16.12	23.93	20.69	20.00	20.48	19.82	23.60	23.27	21.53	18.83
1959	23.91	18.00	23.03	19.75	18.87	19.60	21.36	15.70	23.47	18.05	21.67	19.63	19.59	20.08	18.87	17.62	17.06
1960	22.84	23.34	21.75	19.52	18.86	20.48	20.13	14.47	22.48	18.43	20.82	18.69	19.97	19.74	16.77	17.38	16.44
1961	26.54	18.70	23.54	18.93	20.34	19.37	21.92	16.93	25.59	21.84	20.73	21.26	20.24	21.28	16.42	18.87	17.64
1962	31.71	30.42	27.04	22.78	21.20	22.82	25.54	18.73	27.63	25.12	21.51	23.68	22.77	20.07	18.76	20.48	19.39
1963	24.61	16.75	24.65	20.98	19.38	20.09	21.15	17.48	22.15	22.32	18.40	20.55	21.27	19.87	18.44	19.95	14.08
1964	18.07	13.06	19.34	17.55	16.16	15.08	17.94	13.31	17.67	17.15	13.81	15.11	18.58	13.75	15.25	14.71	14.44
1965	34.38	24.61	25.29	25.36	22.20	21.85	27.54	17.39	22.57	24.40	21.90	21.99	27.87	23.86	20.39	21.26	20.30
1966	16.98	18.88	20.06	19.48	15.70	18.04	22.94	14.18	18.79	20.35	21.14	20.26	22.45	18.68	18.95	18.72	19.58
1967	22.07	20.72	17.95	16.43	13.67	13.75	18.61	14.94	15.90	18.97	17.01	18.14	19.92	16.62	15.93	16.85	16.15
1968	26.27	13.94	16.25	15.34	12.04	16.19	19.63	14.08	17.10	17.42	17.22	17.40	20.64	14.93	14.79	14.30	14.78
1969	31.98	23.12	19.10	16.14	15.90	17.23	21.65	16.88	18.36	17.66	19.88	20.47	20.68	18.06	16.75	15.26	18.53
1970	21.87	14.87	17.97	16.80	14.75	17.39	21.35	14.89	17.83	17.22	19.16	16.68	19.24	17.63	14.11	14.87	17.19
1971	22.69	20.45	21.67	20.67	15.17	17.60	22.75	16.31	20.85	19.50	19.72	19.76	21.05	19.12	15.15	16.60	15.85
1972	27.75	20.26	21.48	18.24	17.65	18.01	21.15	19.21	22.45	21.15	19.96	20.97	20.56	16.81	17.16	16.80	18.48
1973	30.13	27.10	24.24	21.88	21.52	22.53	26.90	20.64	24.82	25.73	22.13	23.11	24.94	21.39	20.65	19.68	20.25
1974	14.87	16.17	19.46	18.48	16.54	19.76	20.34	16.27	19.27	24.48	18.80	19.57	20.92	16.42	17.64	17.16	16.05
1975	21.89	17.92	20.24	21.32	16.80	22.26	22.73	16.24	22.84	21.49	20.43	21.59	23.22	20.95	17.60	16.46	19.04
1976	20.80	11.83	16.16	16.85	11.99	16.11	17.87	11.95	20.78	14.50	19.88	18.94	19.60	15.98	13.57	12.42	12.00
1977	30.47	22.28	24.35	22.37	15.63	19.32	27.30	16.50	21.77	18.88	18.73	19.23	22.16	19.91	14.23	14.38	16.85
1978	23.72	16.44	19.60	16.62	13.62	17.18	20.89	15.94	18.67	19.90	18.19	18.74	18.68	16.24	13.56	13.79	16.88
1979	34.91	19.78	20.50	20.13	16.59	22.23	23.97	22.44	20.05	20.31	20.48	21.06	24.91	20.30	20.38	19.99	18.84
1980	20.79	16.27	19.03	17.15	18.05	18.40	19.21	24.12	19.57	21.42	16.71	19.44	22.15	18.07	22.50	22.26	19.20
1981	31.11	22.64	26.18	23.34	21.19	21.97	22.96	23.28	21.33	27.58	19.00	19.52	22.99	23.42	25.58	24.57	17.89
1982	30.36	26.94	28.99	28.97	19.67	24.67	22.57	24.98	21.73	27.23	23.36	19.13	24.94	24.35	22.44	22.06	20.07
1983	30.82	17.07	22.80	26.08	19.53	19.71	20.15	20.74	19.27	22.48	16.96	14.04	26.68	21.86	18.79	19.31	17.31
1984	25.31	21.19	25.05	25.94	16.65	20.05	20.97	20.62	22.90	21.49	19.45	7.20	26.89	22.66	17.91	19.09	21.76
1985	28.87	16.82	23.81	21.36	16.63	21.20	20.44	21.28	22.54	21.67	17.96	14.73	26.11	21.94	16.73	18.90	19.71
1986	20.93	18.58	20.33	18.57	15.55	19.23	20.04	17.92	19.39	18.51	15.40	14.43	22.62	19.03	15.87	17.18	16.91
1987	35.70	21.14	20.89	19.21	19.56	19.12	22.34	18.65	18.81	22.78	17.01	17.67	23.76	19.11	16.94	18.19	21.26
1988	21.11	17.53	20.12	17.28	18.77	18.02	19.96	19.97	16.16	22.99	16.08	18.73	22.32	18.07	17.70	19.58	19.24
1989	20.15	14.61	16.04	14.46	16.48	18.07	17.03	19.06	15.44	20.94	16.97	17.06	19.06	17.28	15.52	17.29	15.27
1990	23.13	19.12	19.00	19.31	17.15	18.06	19.29	19.14	19.87	21.93	18.00	19.12	19.67	22.75	19.27	20.31	15.12
1991	21.29	20.65	22.86	20.40	19.15	18.54	20.85	21.57	21.85	22.30	20.01	15.23	23.04	23.47	22.24	25.82	13.98
1992	26.00	20.17	24.12	24.18	20.09	23.20	25.01	22.78	26.55	24.01	22.54	16.31	23.94	25.51	20.12	23.08	20.02
1993	37.45	25.23	28.55	25.82	20.02	28.23	30.90	26.05	32.34	23.40	27.11	21.57	28.86	27.50	19.99	20.09	23.45
1994	22.95	19.01	26.42	24.51	17.66	26.51	28.09	20.21	25.15	22.45	22.54	22.20	26.72	25.64	16.07	17.46	19.70
1995	24.31	16.12	23.72	22.51	18.83	23.74	22.68	20.04	24.02	23.15	20.62	19.60	20.87	23.93	18.93	19.27	19.74
1996	31.79	26.04	27.55	20.93	19.04	24.76	26.52	19.37	24.98	23.90	18.79	21.52	22.70	21.67	17.96	20.82	21.40
1997	24.91	15.80	23.96	18.32	18.44	22.16	23.39	19.05	22.28	20.12	20.06	20.21	19.71	21.51	16.24	18.84	19.98
1998	19.95	16.79	22.04	19.88	18.85	22.11	21.02	18.51	20.83	20.09	21.13	21.72	18.64	22.53	17.15	19.44	21.16
1999	22.25	23.11	22.38	20.35	19.91	20.33	21.12	19.53	20.88	20.34	21.27	20.66	21.10	22.04	16.73	18.74	20.89
2000	28.69	17.12	20.41	18.31	17.43	17.86	18.89	19.07	18.31	19.30	19.45	19.14	18.16	17.62	15.42	17.50	17.82
2001	24.66	2.52	21.92	19.84	19.20	18.01	22.40	17.84	20.82	20.02	19.65	21.02	19.72	18.37	15.37	15.50	15.94
2002	17.15	8.62	14.64	14.88	13.81	15.44	17.00	12.91	14.66	14.67	13.69	17.64	15.27	16.19	13.97	11.38	11.93
2003	21.14	17.23	16.94	14.54	15.04	14.68	15.19	13.00	12.97	14.15	13.09	13.93	15.23	14.76	13.78	10.80	10.51
2004	25.15	22.50	21.06	18.70	17.70	17.77	19.06	18.06	17.24	18.48	16.46	16.98	20.73	18.00	14.57	15.39	17.71
2005	24.65	16.81	22.65	23.12	19.71	20.77	21.78	17.49	22.94	20.90	20.22	20.96	24.26	21.67	18.60	20.99	16.37