Kansas Geological Survey Open-File Report 2009-20*
Smoky Hill River Model Scenario-
Impacts of Ground-water Pumping and Stream Diversions on Streamflow
Supplement to KGS Open-file Report 2008-20

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*Addendum added August 13, 2009

Introduction

In the spring of 2009, the Kansas Water Office (KWO) requested an additional scenario to be run with the Smoky Hill River ground-water model constructed previously by the Kansas Geological Survey (KGS) (see Wilson et al., 2008, KGS Open-file Report 2008-20). The purpose of this additional scenario is to evaluate the impacts of ground-water pumping and surface-water diversions on the Smoky Hill River flow. Based on discussion with the KWO, two sets of simulations were conducted for the evaluation: 1) no ground-water pumping occurs from the hydrologically connected alluvial aquifer, 2) no surface-water diversions are taken from the river. The new simulation results were compared to those in the original base transient model run.

Much like the previous modeling runs, this additional scenario is focused on low streamflow conditions during below-normal precipitation periods. The periods investigated in detail are based on the average summer or growing season (March to September) conditions for the drought years of 1953 to 1956 and 2002 to 2006. These periods were compared to the average results for both winter and summer time steps from 1962 to 2006, and represent the primary period used in the original transient model runs for post-channelization of the Smoky Hill River. Single year comparisons were conducted for the summer months of the drought years 1956, 1991, 2002, and 2006.

The 1950s and 2000s periods, both notable droughts, were selected for comparison purposes although each period represents very different conditions in streamflow and amount of pumping from both ground- and surface-water sources. The 1950s period pre-dates the Mentor flood-control diversion works and channelization on the Smoky Hill River in and upstream of Salina.

Characteristics of Scenario Focus Years

Flow in the Smoky Hill River was relatively low from winter 1953 to winter of 1957, winter 1989 to winter 1992, and summer 2002 to summer 2006 (Figure 1). The amount of ground-water discharging to the river was smaller and the quantity of net storage lost from the alluvial aquifer was larger than average during these periods as indicated by Figures 74 and 76, respectively, in Wilson et al. (2008). The minimum flow required from Kanopolis Reservoir release as simulated in the back-calculation scenario was substantial for these drought years. For example, the minimum reservoir releases needed to sustain a 20 cfs flow in the Smoky Hill River at Salina were estimated as 42, 34, 35, and 15 cfs, respectively, for the summers of 1956, 1991, 2002, and 2006.

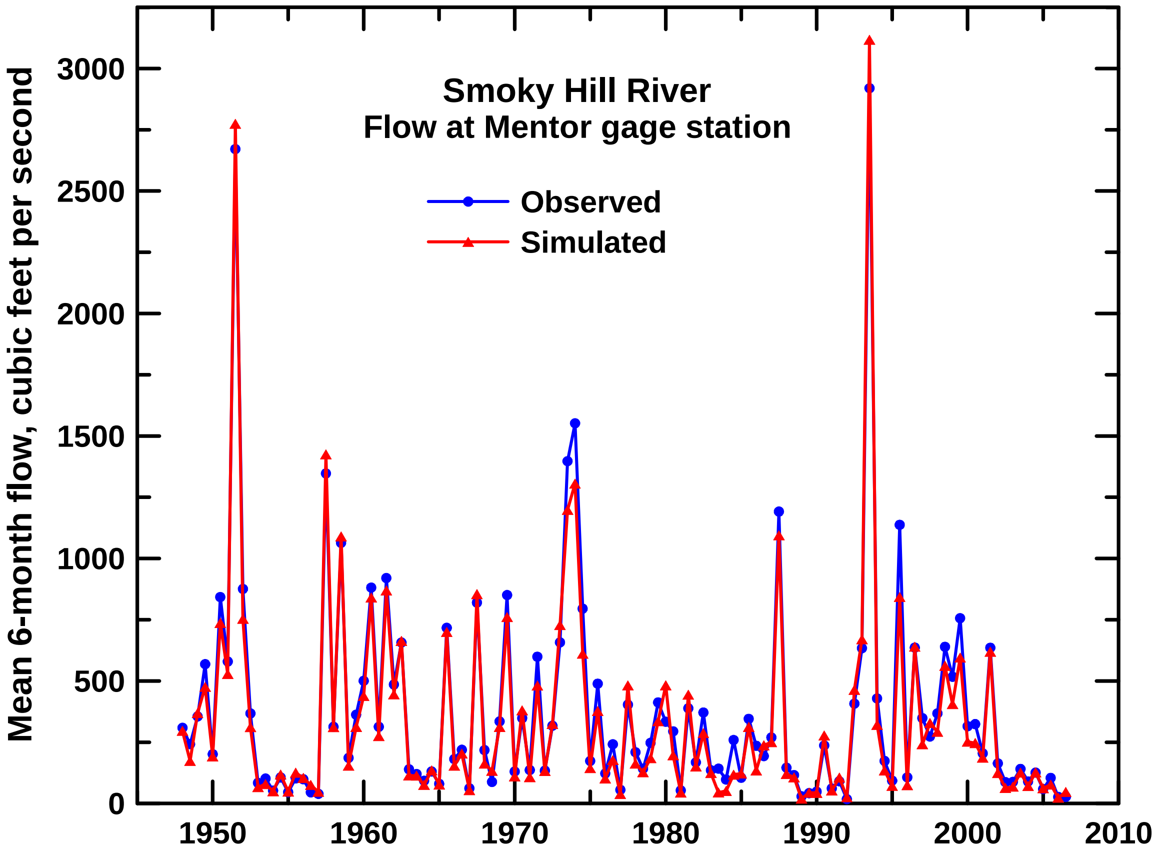

Figure 1. Simulated and observed flow in the Smoky Hill River at Mentor (simulated flows from original base transient model run).

Scenario Results, Multi-Year Averages

Average streamflow was calculated for 1962-2006 and the summer months of 1953-1956 and 2002-2006 (Figures 2, 3, and 4, respectively) for the base transient (aka *base*), no ground-water pumping (aka *noGW*), and no surface-water diversions (aka *noDiv)* conditions. A tabular breakdown of the streamflow at each of the gage stations and model end is shown for each time period and scenario in Tables 1, 2, and 3. The tables include the percent difference between the scenario and base case conditions.

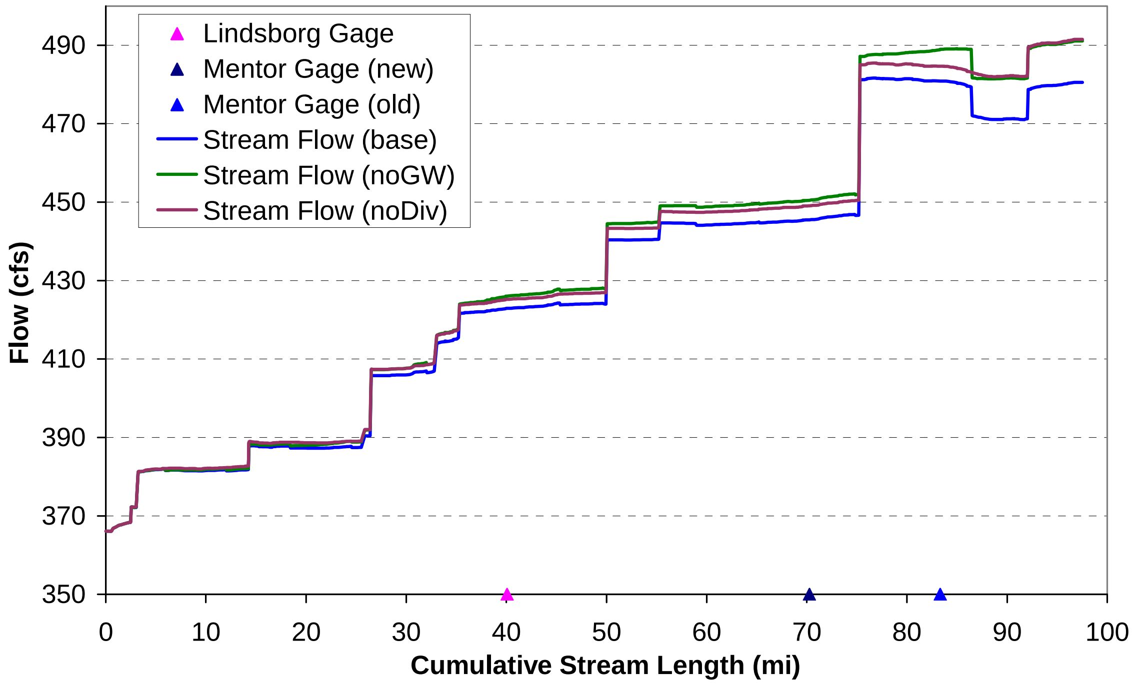

Figure 2- Average streamflow along the Smoky Hill River, 1962 to 2006 (including both summer and winter months)

Table 1 **Average Streamflow, 1962 to 2006**			
Location	**Base**	**NoGW (% from Base)**	**NoDiv (% from Base)**
Lindsborg Gage	422.9	426.1 (0.76%)	425.2 (0.54%)
Mentor Gage (new)	445.5	450.5 (1.12%)	449.1 (0.81%)
Mentor Gage (old)	480.9	489.0 (1.68%)	484.7 (0.79%)
End of Model	480.6	491.1 (2.18%)	491.5 (2.27%)

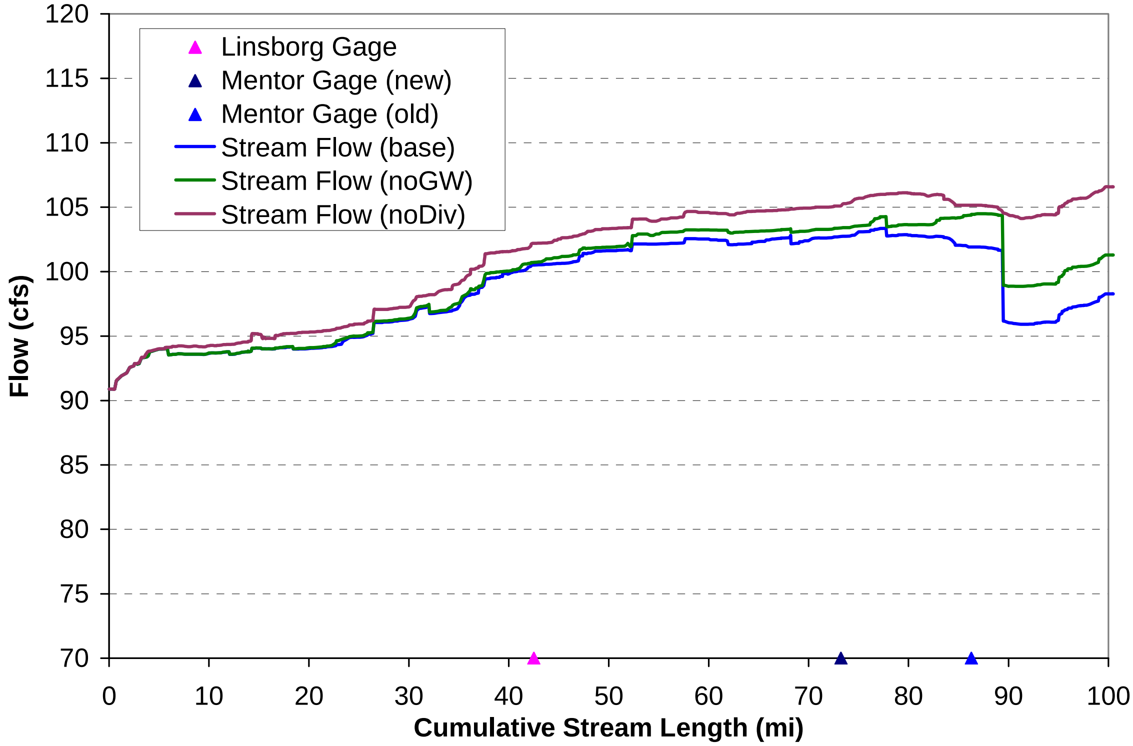

Figure 3- Average streamflow along the Smoky Hill River, summer months, 1953 to 1956.

Table 2
Average Streamflow (cfs), Summer Months 1953 to 1956

Location	Base	NoGW (% from Base)	NoDiv (% from Base)
Lindsborg Gage	99.8	100.0 (+0.20%)	101.6 (+1.80%)
Mentor Gage (new)	102.6	103.2 (+0.58%)	105.0 (+2.34%)
Mentor Gage (old)	102.7	104.1 (+1.36%)	105.9 (+3.12%)
End of Model	98.3	101.3 (+3.05%)	106.6 (+8.44%)

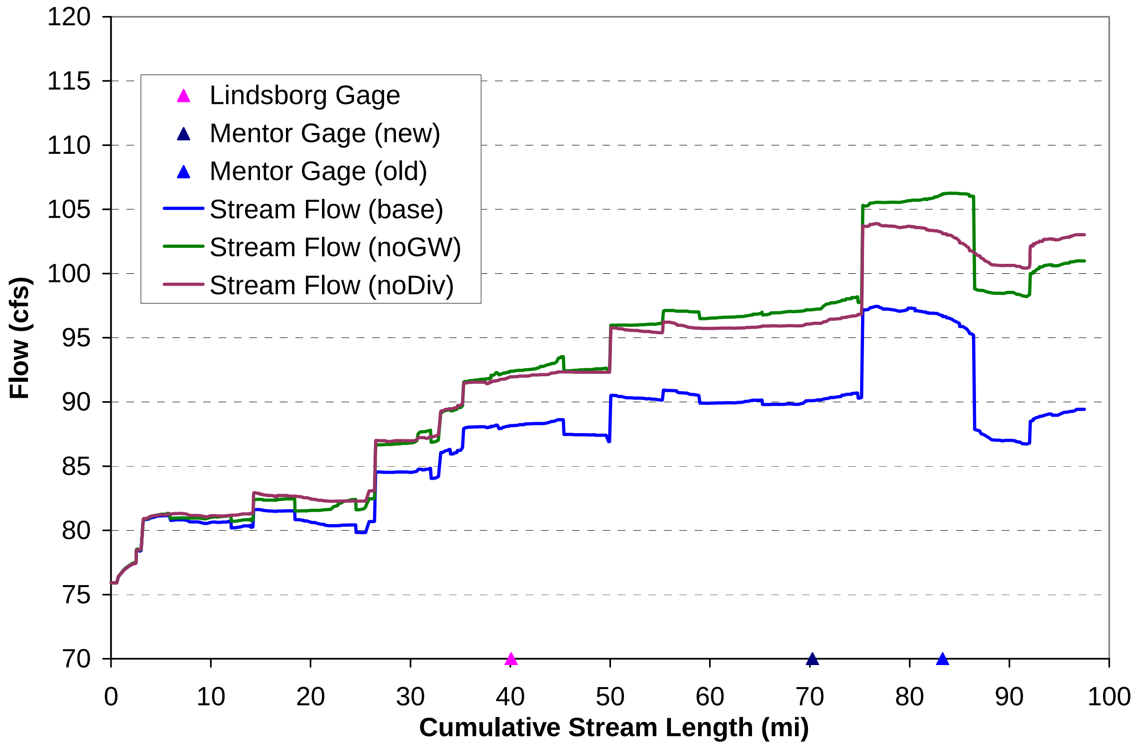

Figure 4- Average streamflow along the Smoky Hill River, summer months, 2002 to 2006

Table 3
Average Streamflow (cfs), Summer Months 2002 to 2006

Location	Base	NoGW (% from Base)	NoDiv (% from Base)
Lindsborg Gage	88.2	92.2 (+4.76%)	92.0 (+4.31%)
Mentor Gage (new)	90.1	97.2 (+7.88%)	96.1 (+6.66%)
Mentor Gage (old)	96.6	106.2 (+9.94%)	103.1 (+6.73%)
End of Model	89.4	101.0 (+12.98%)	103.0 (+15.21%)

Results over the three periods of 1962-2006, 1953-1956, and 2002-2006 indicate the average streamflow will increase if either ground-water pumping or surface-water diversions are stopped. In the case of 1962-2006, the high streamflows during above normal precipitation years mask the overall effects of water use on streamflow (see low percentages in table 1). In all three periods, the notable reduction of flow just past the old Mentor gage location is likely caused by the City of Salina's surface-water right, which is the largest in the model area.

In the 1953-1956 period, ground-water pumping was not yet extensively developed, resulting in little difference when removed from the base run. The large inflow spike from the Mentor cutoff is also noticeably absent during this period as the flood-control structures were not yet constructed. Surface-water diversions, on the other hand, show a significant impact, particularly near the City of Salina where the streamflow in the base case is abruptly dropped by 7.5 cfs as compared to that in the no stream diversion case (aka noDiv).

The average 2002-2006 results represent current water-right development and show that although the absolute differences between the model scenario and base runs are about the same as for the overall transient period from 1962 to 2006, the relative percent deviations from the base run are higher. This is because the streamflow was lower during this period of extended drought than the average over 1962-2006.

Figures 5, 6, and 7 show the stream-aquifer interactions along the river for the periods 1962-2006, 1953-1956, and 2002-2006, respectively, for base case, no ground-water pumping (*noGW*), and no surface-water diversions (*noDiv).* The impact of the alluvial aquifer on streamflow depends heavily on the water table elevation. Higher water tables provide higher baseflow contributions because the gradient between ground- and surface-water levels is larger. In all cases, the cumulative stream-aquifer interactions are slightly smaller in the no surface-water pumping scenario than in the base transient run because of the loss of irrigation return flows from surface water rights (return flows recharge the aquifer and elevate ground-water levels along the river).

Irrigation return flows from both ground- and surface-water applications were dealt with in the overall pumping file used by the model, known as the “well file”. The “well file” accounted for ground-water based irrigation return flows by subtracting that amount from the gross diversions to compute a net ground-water pumping. Return flow from surface-water based irrigation rights were treated as small injection wells in the model. Ground-water pumping and ground- and surface-water return flows were computed at the model cell level (0.25 by 0.25 miles).

In the no ground-water pumping scenario, all model cells in the alluvial aquifer with negative values (net removal of water from the aquifer) in the well file were changed to zero. In the no surface-water diversion scenario, all model cells in the well file with positive values (net gain of water to the aquifer) were changed to zero as the irrigation return flow from surface diversions no longer occurred. A small number of model cells have both ground-water pumping and surface-water diversions, and thus have combined irrigation return flows from ground- and surface-water application. These cells were not properly accounted for by the simple procedure described above. Precisely accounting for ground-water pumping and surface-diversion return flows in these combined cells would require modifying the programming code used to generate the pumping file and re-running the large and computationally extensive procedure. It is expected that this adjustment would only slightly improve the scenario results (e.g., likely less than a percent) and would not alter the conclusions of this report.

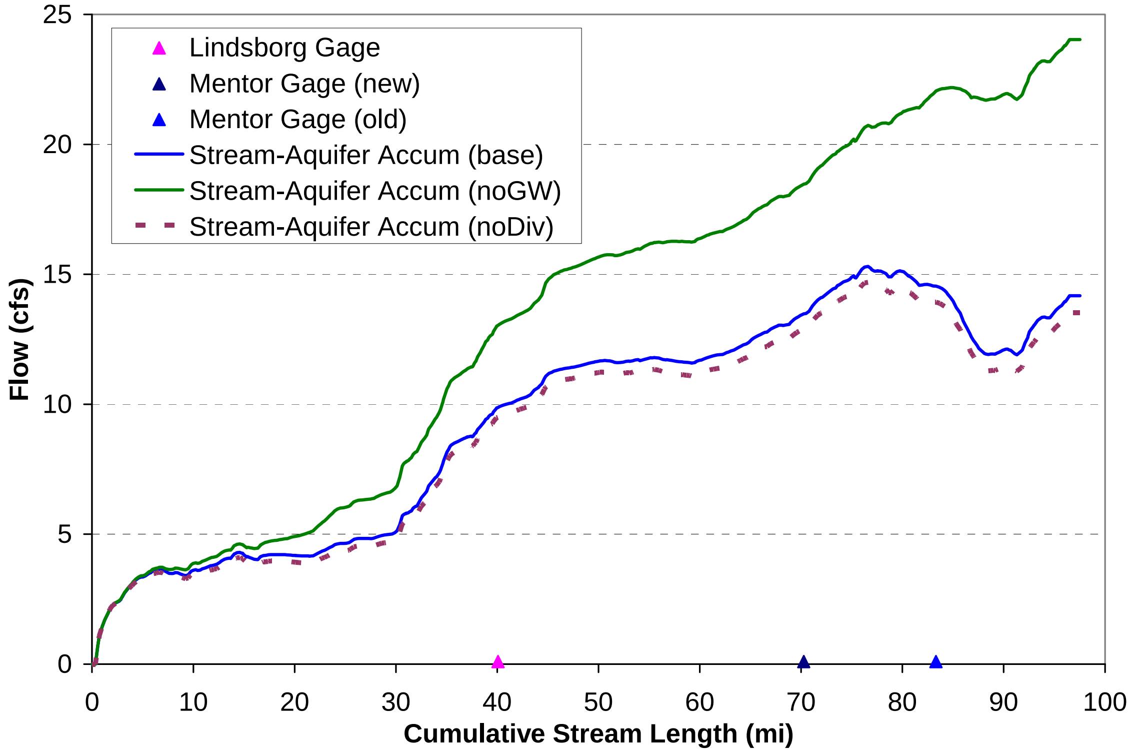

Figure 5- Cumulative stream-aquifer interactions along the Smoky Hill River, averaged from 1962 to 2006 (including both summer and winter months)

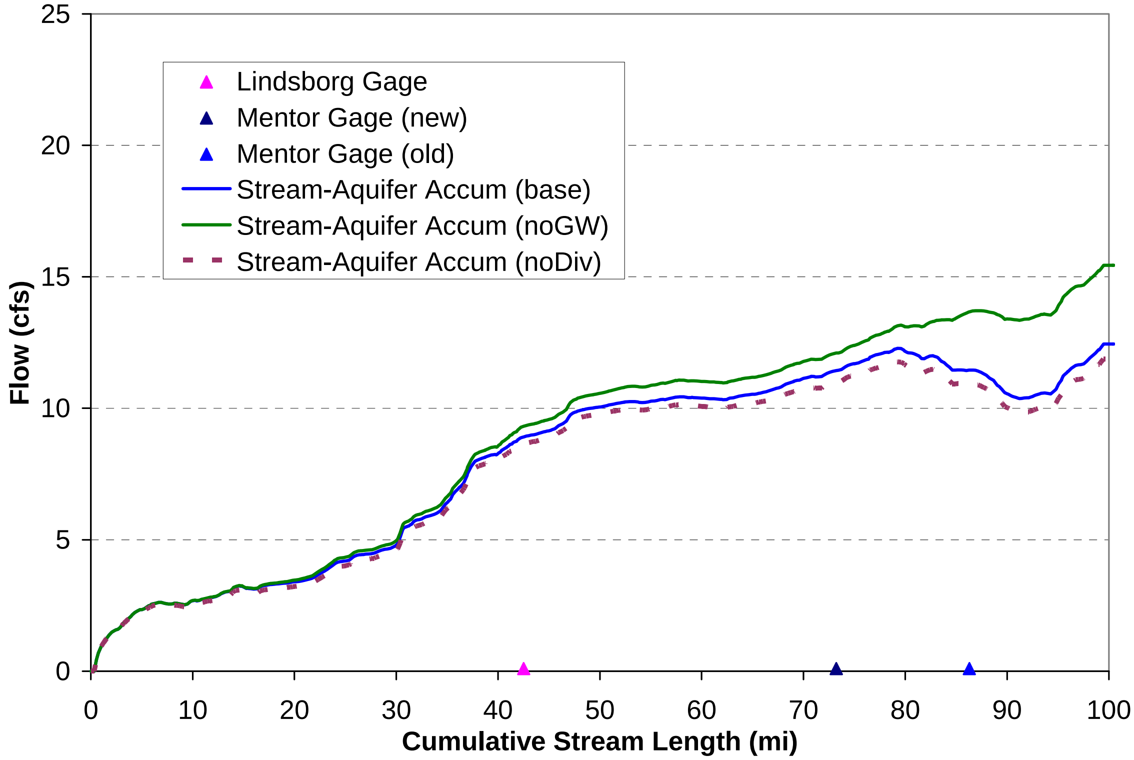

Figure 6- Cumulative stream-aquifer interactions along the Smoky Hill River, summer months, averaged from 1953 to 1956

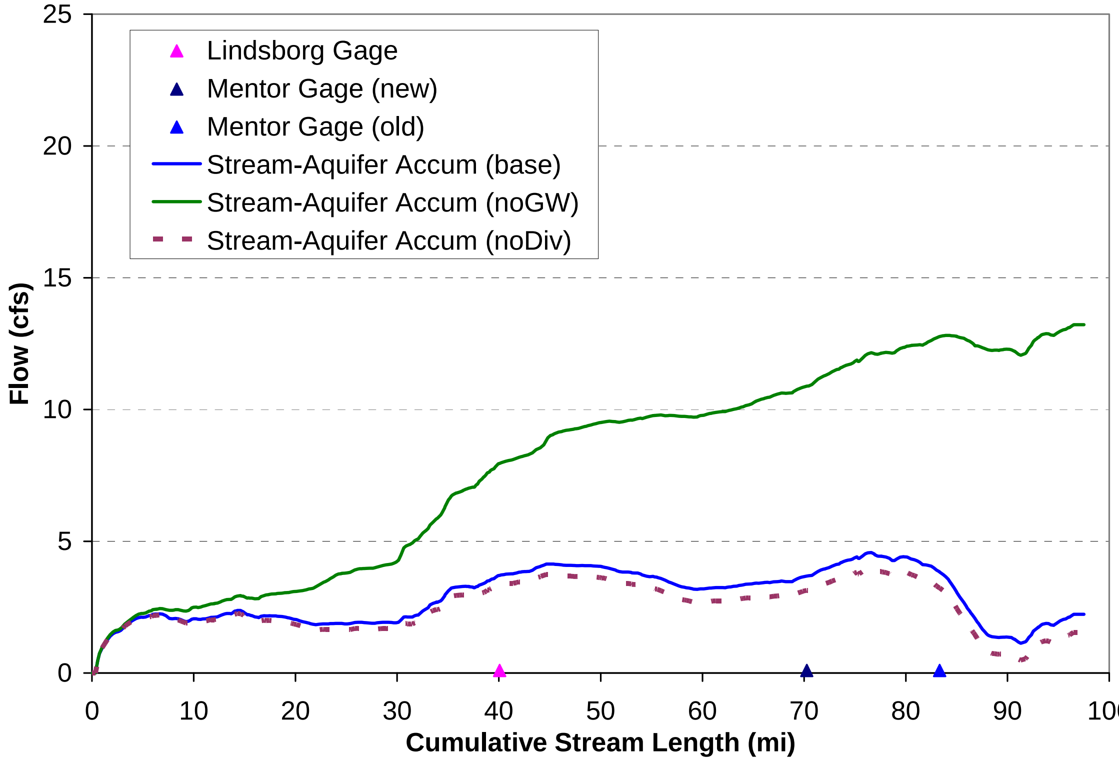

Figure 7- Cumulative stream-aquifer interactions along the Smoky Hill River, summer months, averaged from 2002 to 2006

The separation of the lines for streamflow for each of the model runs in Figures 2-4 generally increases once the river reaches the area around the city of Marquette. The aquifer upstream of this point is thin and narrow relative to other areas of the model. In addition, there were few water demands from either surface or ground-water based water right development in this area.

In every period for all scenarios, the river gains water from the hydrologically connected alluvium except when it reaches the Salina area where ground-water levels appear to be close to streambed elevations. In the base and no surface diversion cases, ground-water pumping produces significant drawdown in the area and produces a notable water loss from the river into the aquifer (see the sharp decreases on the *base* and *noDiv* curves relative to the flat *noGW* curves near Salina in Figures 5-7). Overall, the stoppage of all ground-water pumping allows for more ground water to be transferred to the stream as baseflow, resulting in higher streamflow.

Scenario Results, Single-Year Averages

In addition to average streamflow conditions over a number of summer periods, several single-year summer periods were also investigated in detail. These include 1956, 1991, 2002, and 2006. Figures 8, 9, 10, and 11 show streamflow conditions for the summer periods of 1956, 1991, 2002, and 2006, respectively. A tabular breakdown of the simulated streamflow at each of the gages stations and model end is shown for each time period and scenario in Tables 4-7.

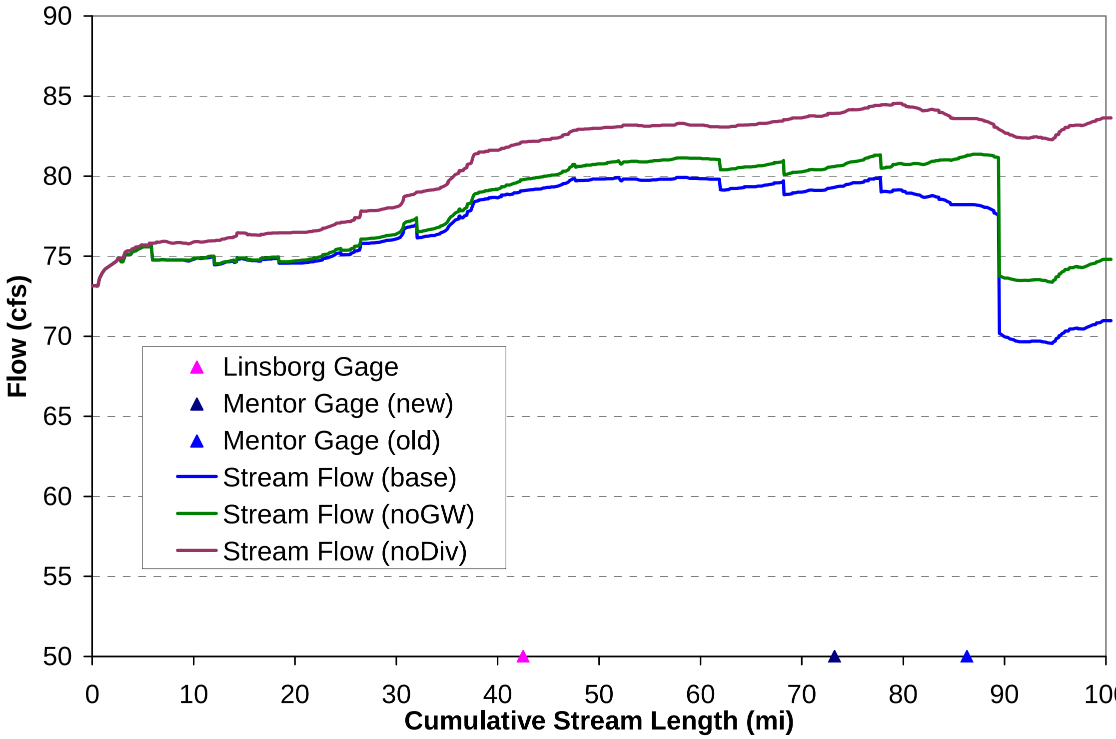

Figure 8- Average streamflow in the Smoky Hill River, summer 1956.

Table 4 Average Streamflow (cfs), Summer 1956			
Location	**Base**	**NoGW (% from Base)**	**NoDiv (% from Base)**
Lindsborg Gage	78.6	79.2 (+0.76%)	81.6 (+3.82%)
Mentor Gage (new)	79.0	80.3 (+1.65%)	83.7 (+5.95%)
Mentor Gage (old)	78.7	81.0 (+2.92%)	84.1 (+6.86%)
End of Model	71.0	74.8 (+5.35%)	83.6 (+17.75%)

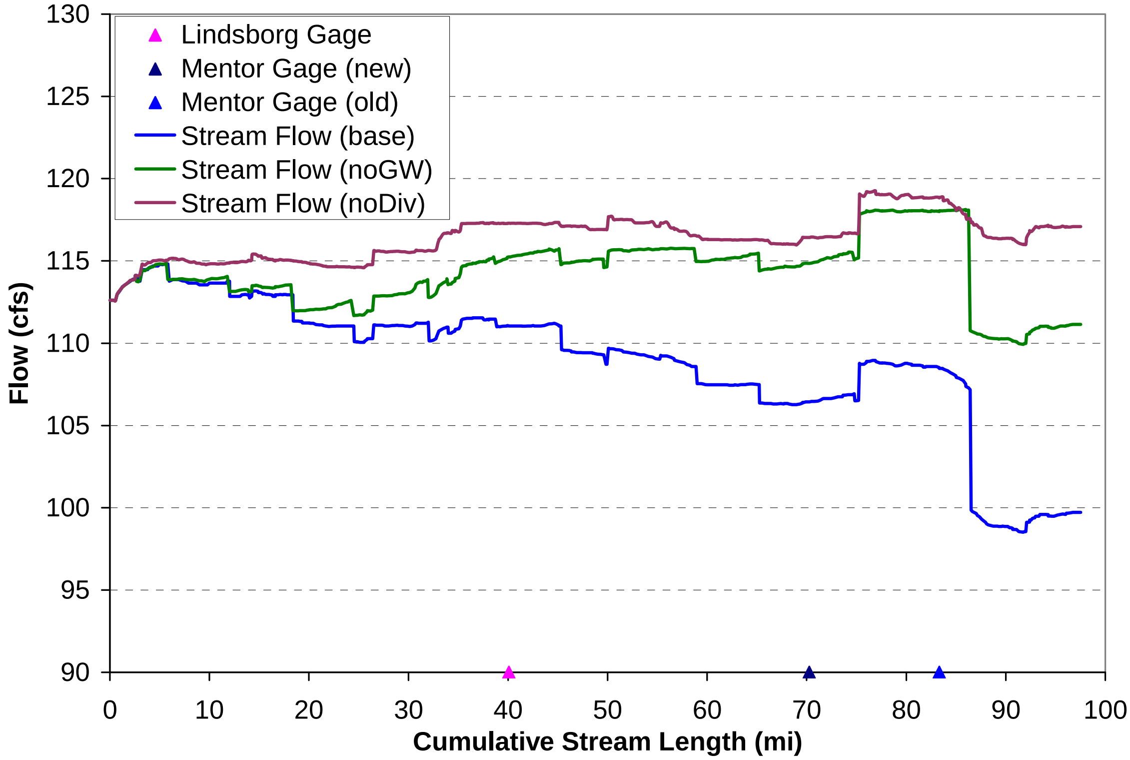

Figure 9- Average streamflow in the Smoky Hill River, summer 1991.

Table 5 Average Streamflow, Summer 1991			
Location	**Base**	**NoGW (% from Base)**	**NoDiv (% from Base)**
Lindsborg Gage	111.1	115.2 (3.699%)	117.3 (5.58%)
Mentor Gage (new)	106.4	114.9 (7.99%)	116.4 (9.40%)
Mentor Gage (old)	108.5	118.1 (8.85%)	118.8 (9.49%)
End of Model	99.7	111.1 (11.43%)	117.1 (17.45%)

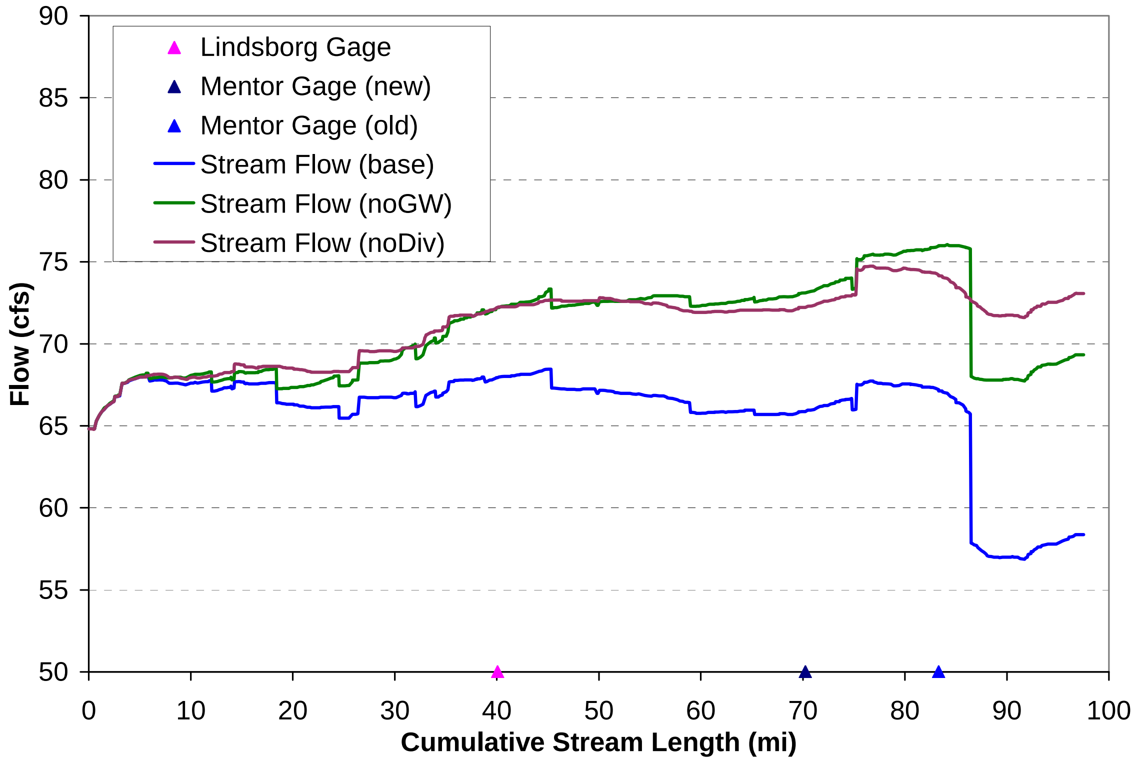

Figure 10- Average streamflow in the Smoky Hill River, summer 2002

Table 6 **Average Streamflow (cfs), Summer 2002**			
Location	**Base**	**NoGW (% from Base)**	**NoDiv (% from Base)**
Lindsborg Gage	67.9	72.2 (+6.33%)	72.2 (+6.33%)
Mentor Gage (new)	65.9	73.1 (+10.93%)	72.2 (+9.56%)
Mentor Gage (old)	67.1	76.0 (+13.26%)	74.2 (+10.58%)
End of Model	58.4	69.3 (+18.66%)	73.1 (+25.17%)

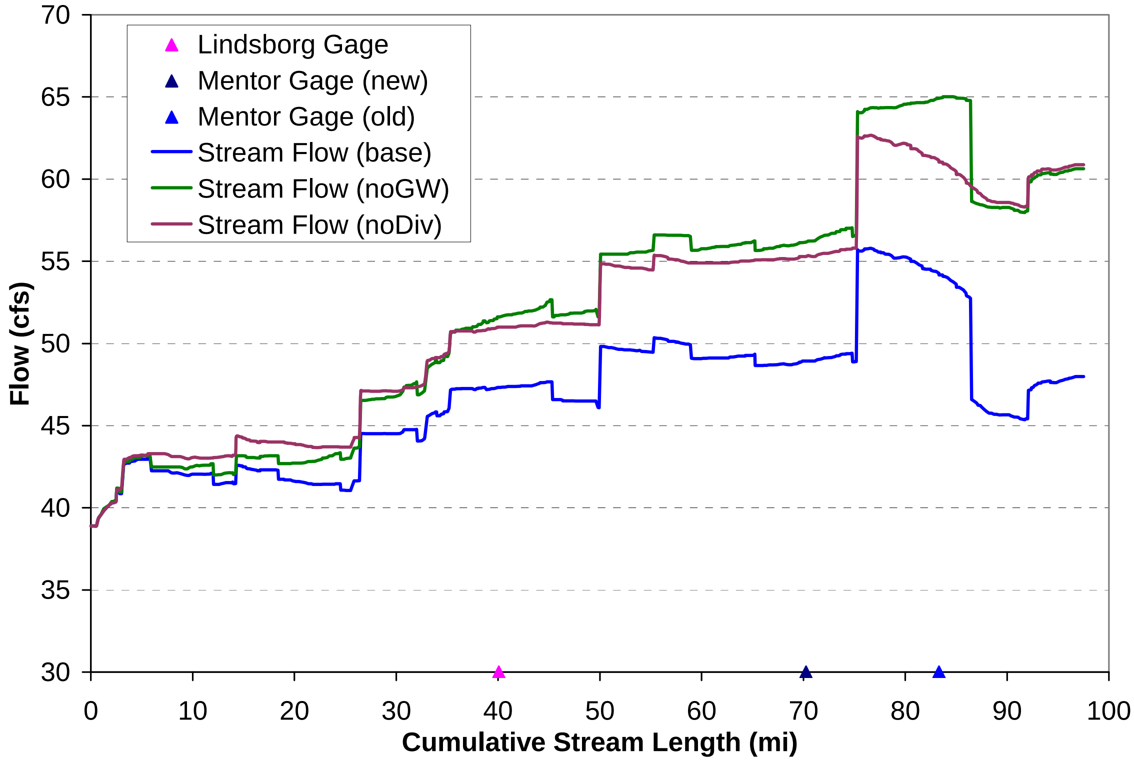

Figure 11- Average streamflow in the Smoky Hill River, summer 2006.

Table 7 **Average Streamflow (cfs), Summer 2006**			
Location	**Base**	**NoGW (% from Base)**	**NoDiv (% from Base)**
Lindsborg Gage	47.3	51.6 (+9.09%)	50.1 (+5.92%)
Mentor Gage (new)	48.9	56.2 (+14.93%)	55.3 (+13.09%)
Mentor Gage (old)	54.2	64.9 (+19.74%)	61.0 (+12.55%)
End of Model	48.0	60.6 (+26.25%)	60.9 (+26.88%)

All of the conditions and patterns seen in the average multi-year drought periods (e.g., 1952-1956 and 2002-2006) hold true for the single-year summer drought period results.

Figures 12, 13, 14, and 15 show the cumulative stream-aquifer interactions along the river for the summer periods of 1956, 1991, 2002, and 2006, respectively. Again, the impact of the alluvial aquifer on streamflow depends heavily on the elevation of the water table. The river is primarily a gaining stream throughout its course. The stoppage of ground-water pumping increases baseflow contributions to the river in all years.

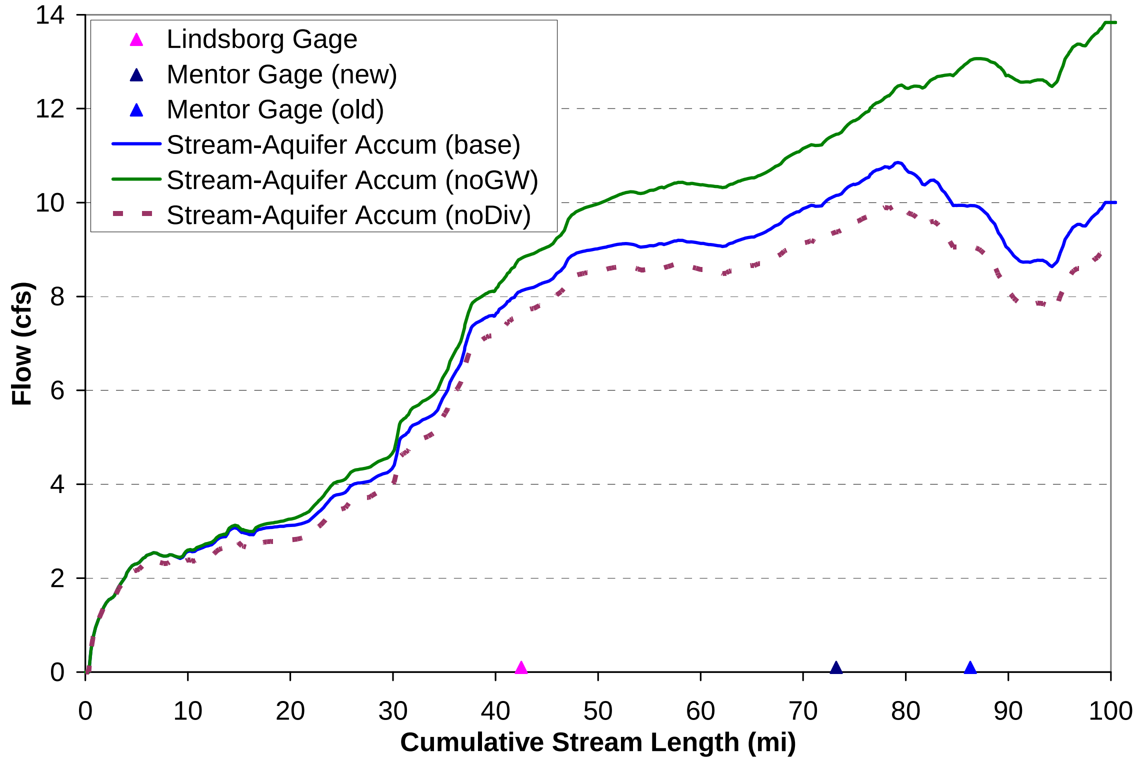

Figure 12- Accumulative stream-aquifer interactions, summer 1956

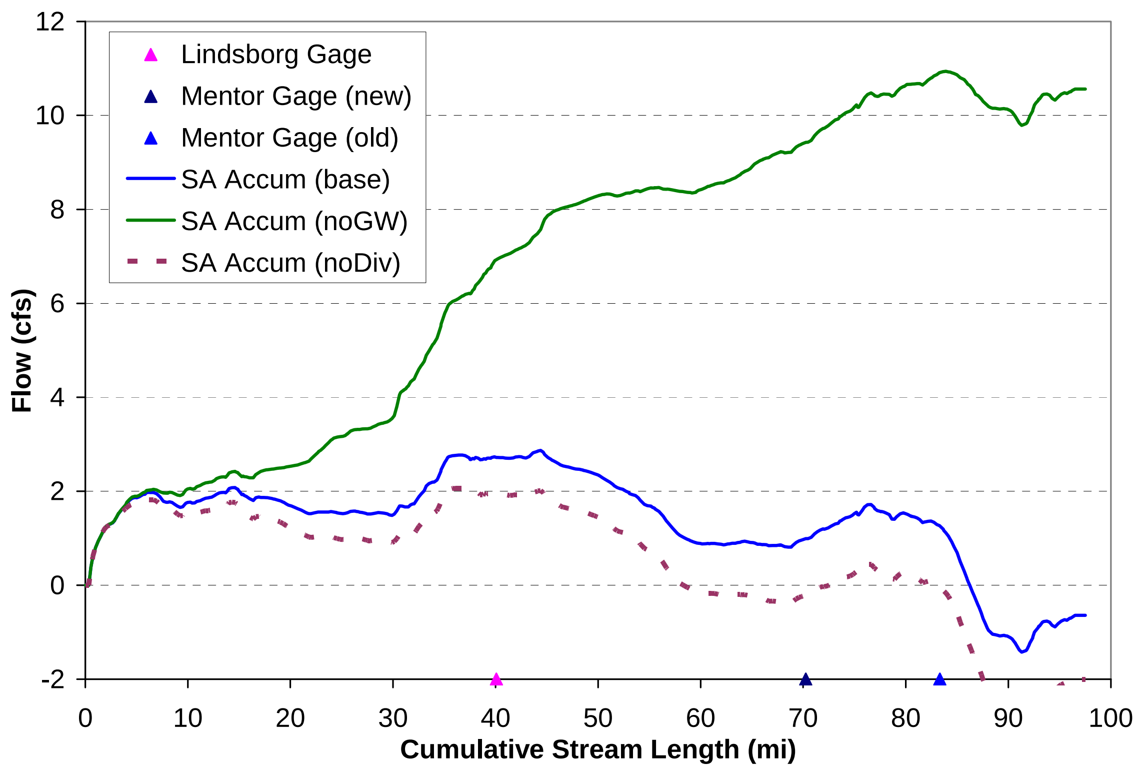

Figure 13- Accumulative stream-aquifer interactions, summer 1991

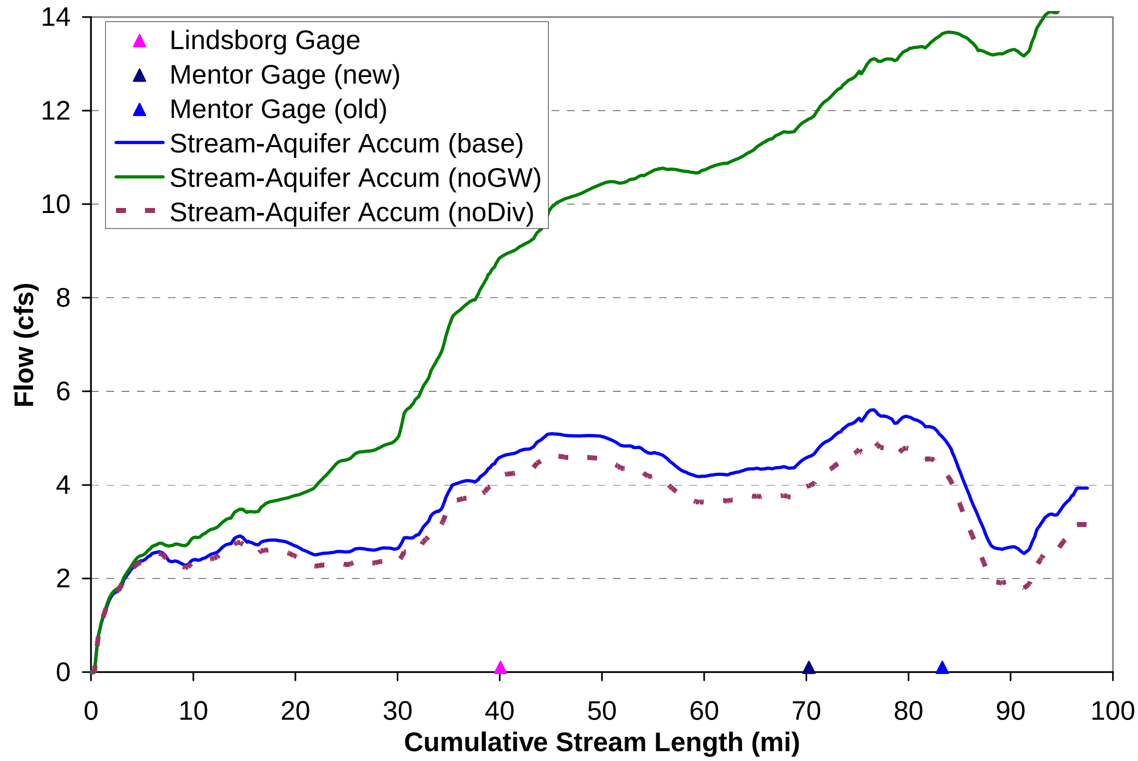

Figure 14- Accumulative stream-aquifer interactions, summer 2002

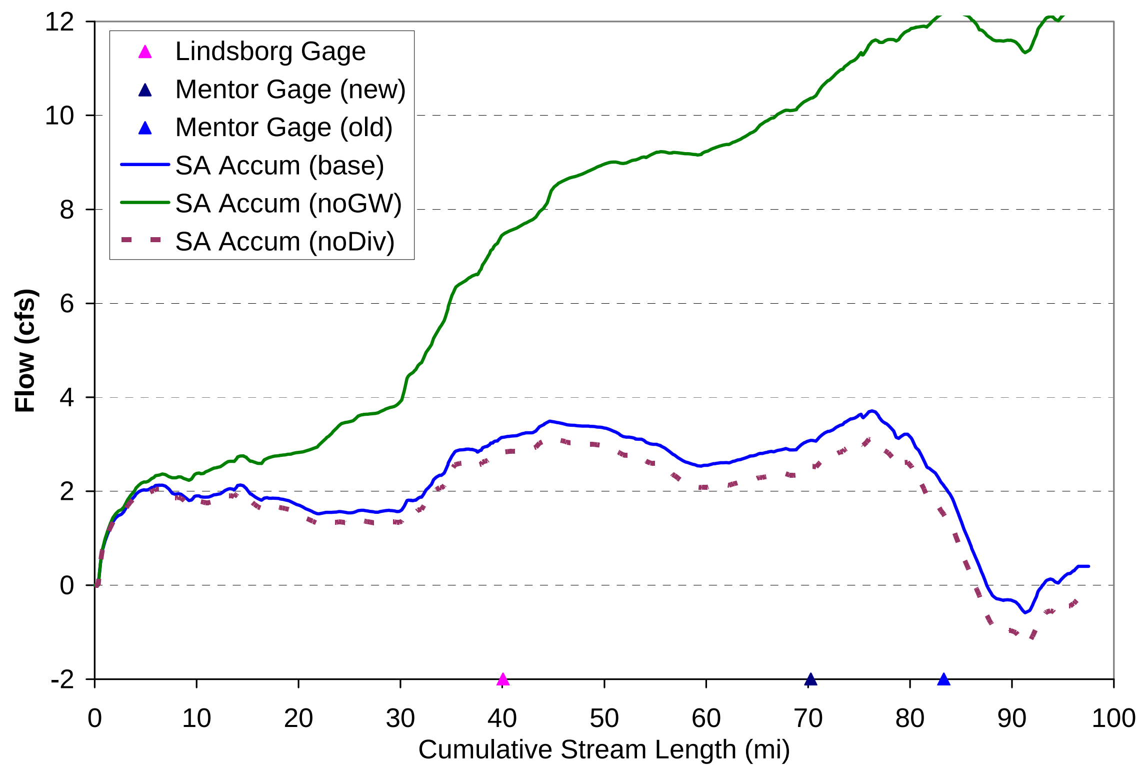

Figure 15- Accumulative stream-aquifer interactions, summer 2006

Conclusion

The Smoky Hill River Valley Ground-water Model was used to evaluate streamflow in the river based on conditions of no ground-water pumping and no surface-water diversions. An evaluation of average conditions over 1962 to 2002 showed smaller percent deviations of streamflow when compared to the base transient model run as a result of high streamflows during the above normal precipitation years. In contrast, an evaluation of scenario results for periods of below-normal streamflow during drought conditions showed significant increases in flow under varying non-water use conditions.

Ground-water pumping impacts streamflow primarily in the rate of baseflow contributions to the river. Higher water-table elevations relative to the stream base elevations allow for larger gradients and increased rates of subsurface flow. With the exception of the average over 1953 to 1956 and the summer of 1991, the river was primarily a gaining stream as it progressed across the model area, even with ground-water pumping in place.

Under present water-right development conditions (2002 to 2006), the impact from ground- or surface-water development appears to be about equal. Differences between the base transient model condition and the no-pumping or no-diversion scenarios generally increase once the river reaches the area around Marquette. At that location, the size of the alluvial aquifer increases both in terms of lateral expanse and overall thickness, allowing for greater water-rights development.

The complete stoppage of all ground-water pumping caused streamflow to increase. This impact was the smallest over the mid-1950s period primarily because ground-water rights had yet to be fully developed. In the more recent time periods, the absolute increase in streamflow for the no ground-water pumping scenario is relatively constant at the measured locations along the river (Lindsborg and Mentor gage sites and end of model) over all the periods investigated. The percent of this increase from the base transient run, however, depends heavily on overall flow volumes. For example, modeled flow rates for summer 2006 increased 26.2% percent in the no ground-water pumping scenario at the end of the model relative to the 18.7% difference in 2002, although the absolute differences from the base transient model run were 12.6 and 10.9 cfs, respectively.

The City of Salina's water rights, both ground and surface sources, appear to have the largest single impact on streamflow of any diversions in the model. Flow abruptly drops just past the old Mentor stream gage location during virtually all periods. The stream-aquifer interactions also change direction indicating the river starts to significantly lose water to the aquifer due to the extensive ground water pumping in the Salina area.

Addendum, August 13, 2009

After the KWO examined the additional scenario results described above, they requested that the KGS run another model scenario in the summer of 2009. This latest scenario again evaluated streamflow but was based on a repeat of the driest climatic interval, 1953 to 1956, over the model period using present day conditions (e.g., present-day stream network, and water-right development). Like the back-calculation scenario (Wilson et al., 2008), surface- and ground-water pumping demands were computed from the linear water-use regressions applied to each climatic period but were always based on their most recent level of water-right development. This means that all uses and all sources diverted water; the amount diverted depended on the level of precipitation. The initial ground-water level, head boundaries, and stream properties (depth, width) were also based on 2006 conditions. The inflows to the Smoky Hill River, 13.67 cfs for the winter months and 41.67 cfs for the summer months, are based on the minimum release schedule from Kanopolis reservoir and remain constant between years. As before, simulations of no ground-pumping (noGW) and no surface-water diversions (noDiv) were compared to the original base transient model run.

The scenario results for the average base model conditions from 1953 to 1956, with both present day ground- and surface-water demands fully satisfied, show that the average flow accumulations in the Smoky Hill River begin a slight and gradual decline as the river moves downstream of Lindsborg (Figure 16). Computed river flow passing the old Lindsborg gage is 41.4 cubic feet-per-second (cfs), which falls to 37.1 and 36.7 cfs at the new and old mentor gage locations, respectively. Flows recover after a notable drop in the Salina area (caused by Salina's relatively large and senior surface water right) just east of the city to an estimated 28 cfs once the river leaves the model area. Drought conditions over the 1953 to 1956 period are apparent in this graph as indicated by the lack of sizable tributary inflow steps seen in other similar model runs, such as in Figure 4.

Present day ground- and surface-water diversions over 1953-1956 have relatively equal impacts on overall flow accumulations in the river. Unlike previous runs where the stoppage of either ground-water pumping or surface-water diversions caused flows in the river to gradually increase, complete restrictions on present-day diversions from either source (ground or surface) produces generally stable flow conditions with only very small gains or losses (generally less than 3 cfs) in the river until it reaches the Salina area where the flow declines significantly (Table 8).

The percent difference in river flow between the base conditions and those of no ground- or no surface-water pumping also gradually increases downstream. By the time the river reaches its confluence with the Saline River (the end of the model), curtailing ground- or surface-water diversions allows for increases of 49.6% and 57.9%, respectively, from the base conditions.

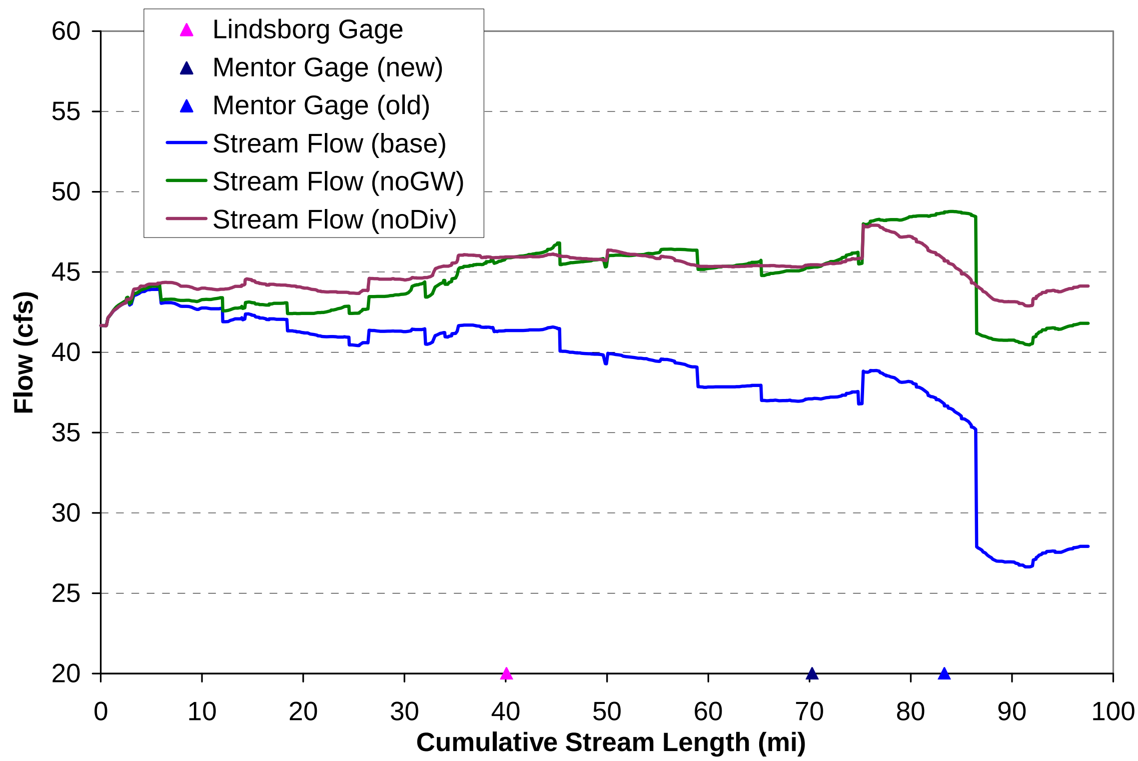

Figure 16- Average streamflow along the Smoky Hill River, 1953 to 1956 (present-day conditions, summer months)

Table 8
Average Streamflow (cfs), Summer Month 1953 to 1956 (present-day water rights)

Location	Base	NoGW (% from Base)	NoDiv (% from Base)
Lindsborg Gage	41.4	45.9 (+10.98%)	45.9 (+10.98%)
Mentor Gage (new)	37.1	45.3 (+22.06%)	45.4 (+22.33%)
Mentor Gage (old)	36.7	48.7 (+32.82%)	45.7 (+24.64%)
End of Model	27.9	41.8 (+49.65%)	44.1 (+57.88%)

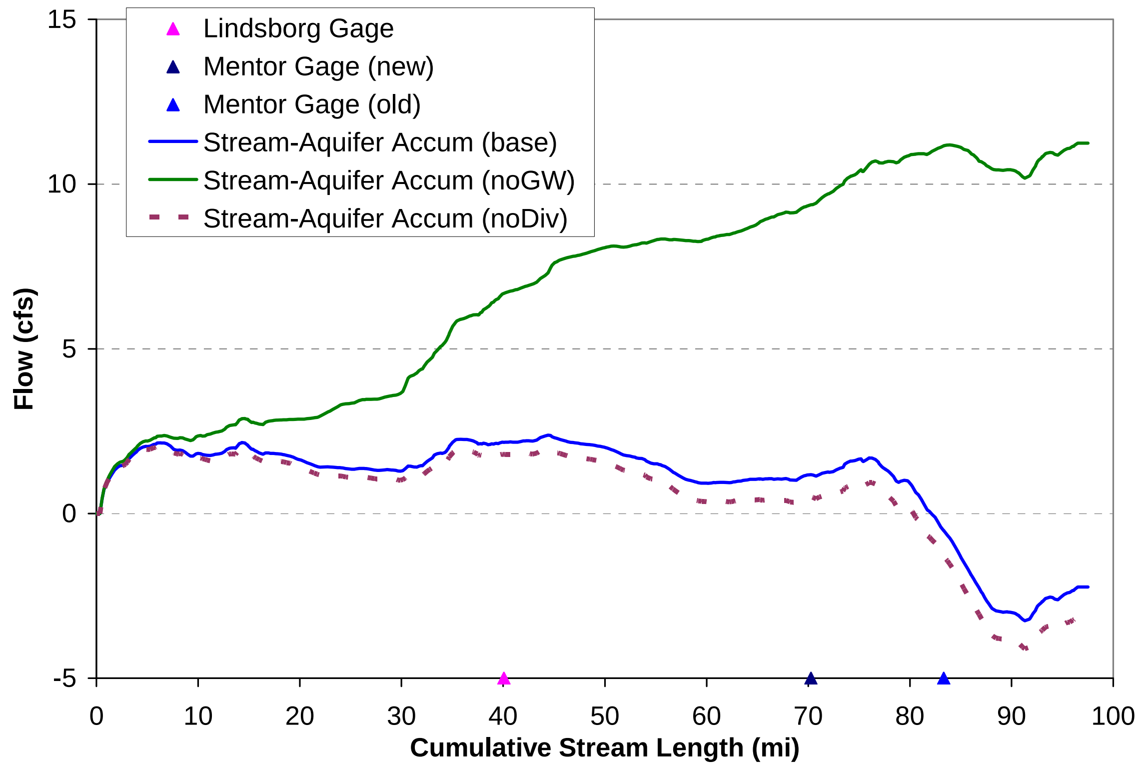

Figure 17- Stream-aquifer interactions along the Smoky Hill River averaged for 1953-1956 (present-day conditions, summer months)

Figure 17 shows the average stream-aquifer interaction along the river over the same model runs, 1953 to 1956 under present-day conditions. In the no ground-water pumping scenario, the model indicates that the river gains water from the aquifer in the form of baseflow throughout almost all of its course. In the base and no surface-water diversion scenarios in which ground-water pumping is occurring, baseflow contributions from the alluvial aquifer to the river are relatively static and small, and start to gradually decline from around the Lindsborg area to Salina, indicating the river is a losing stream. Near the old Mentor gage location just south of Salina, the stream-aquifer interaction crosses the zero line on the graph signifying the overall net baseflow is now negative.

Figures 18 to 21 and Tables 9 to 12 show the single year stream flows from 1953 to 1956, respectively, under present-day conditions. As would be expected, the overall patterns seen in the single year runs mirror those shown in the 1953-1956 averages. Overall, the absolute differences between the scenarios of no ground-water pumping and no surface-water diversions are roughly the same in comparison to the base run. The highest percentage difference between each scenario and the base condition is in 1956, the driest year during the entire model period. The single year 1956 run under present day conditions shows a slight declining slope in stream flow between Lindsborg and Salina, whereas the other years in the period showed streamflow to be relatively static with only minor segments of the river exhibiting increases or decreases in flow of 3 cfs or less.

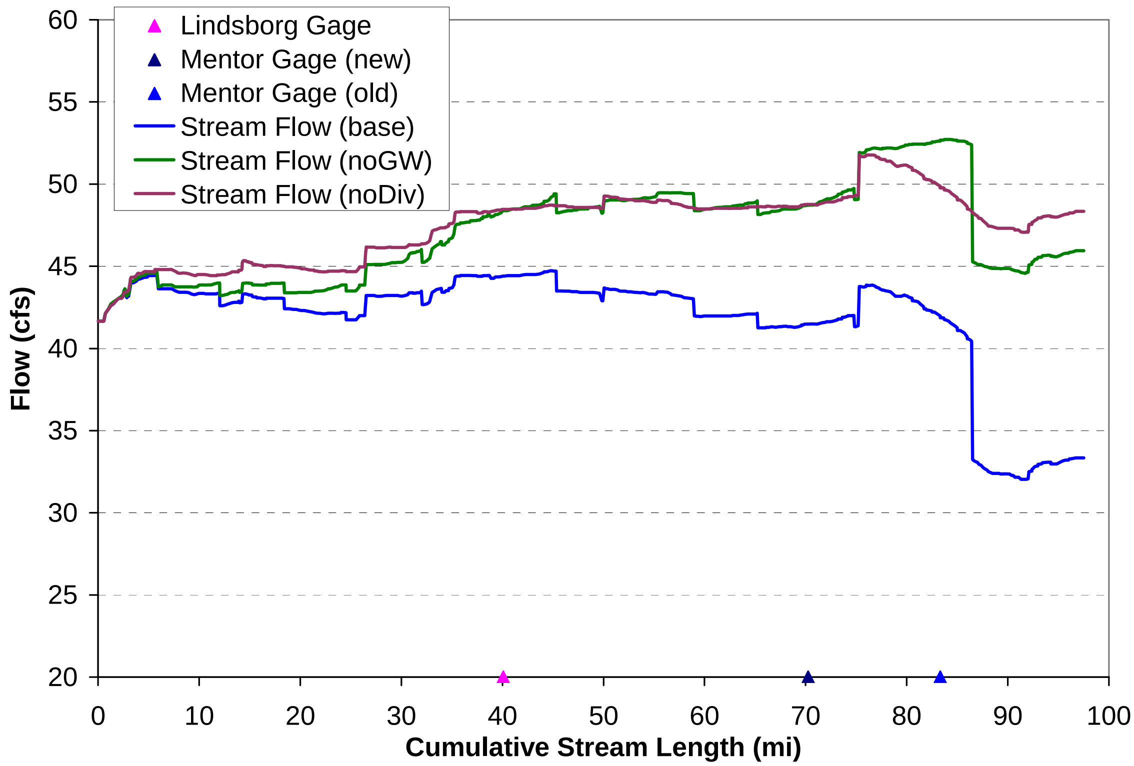

Figure 18- Average streamflow along the Smoky Hill River, summer 1953 (present-day conditions)

Table 9
Average Streamflow (cfs), Summer 1953 (present-day conditions)

Location	Base	NoGW (% from Base)	NoDiv (% from Base)
Lindsborg Gage	44.4	48.4 (+8.95%)	48.5 (+9.12%)
Mentor Gage (new)	41.5	48.7 (+17.44%)	48.8 (+17.58%)
Mentor Gage (old)	41.9	52.7 (+25.79%)	49.9 (+18.84%)
End of Model	33.3	45.9 (+37.85%)	48.3 (+45.02%)

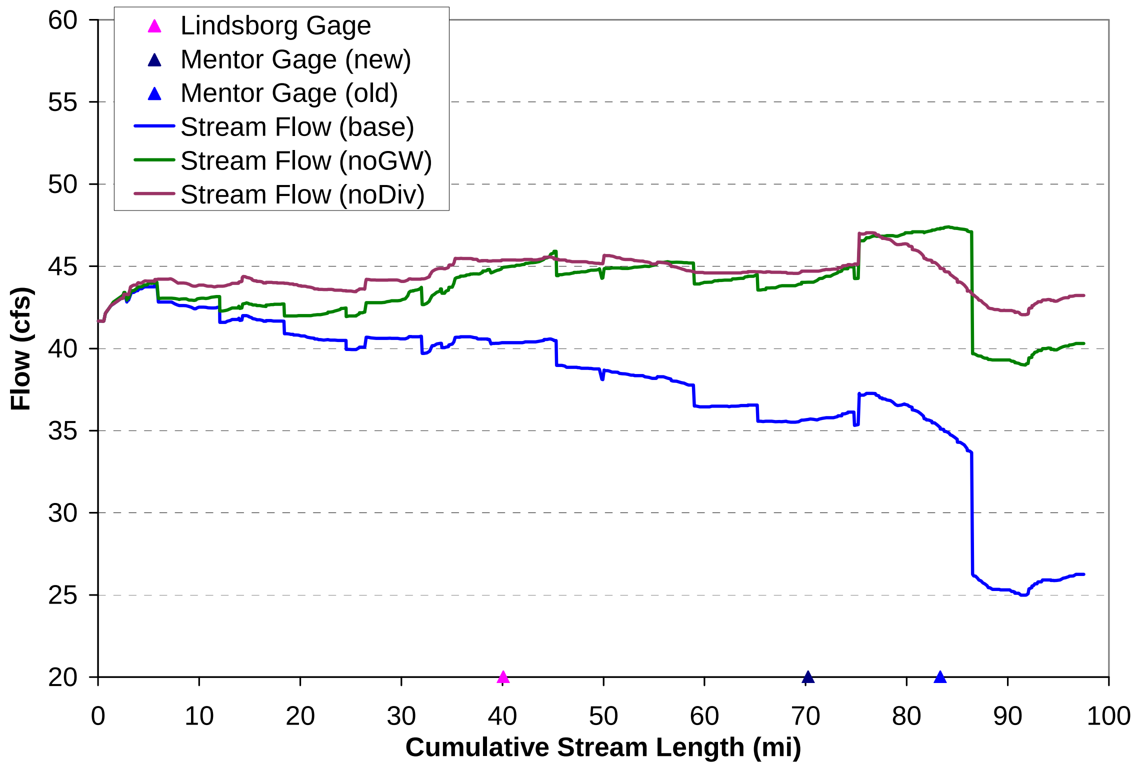

Figure 19- Average streamflow along the Smoky Hill River, summer 1954 (present-day conditions)

Table 10 Average Streamflow (cfs), Summer 1954 (present-day conditions)			
Location	**Base**	**NoGW (% from Base)**	**NoDiv (% from Base)**
Lindsborg Gage	40.4	44.9 (+11.33%)	45.4 (+12.48%)
Mentor Gage (new)	35.7	44.0 (+23.47%)	44.7 (+25.31%)
Mentor Gage (old)	35.1	47.3 (+35.85%)	44.9 (+27.87%)
End of Model	26.3	40.3 (+53.49%)	43.2 (+64.66%)

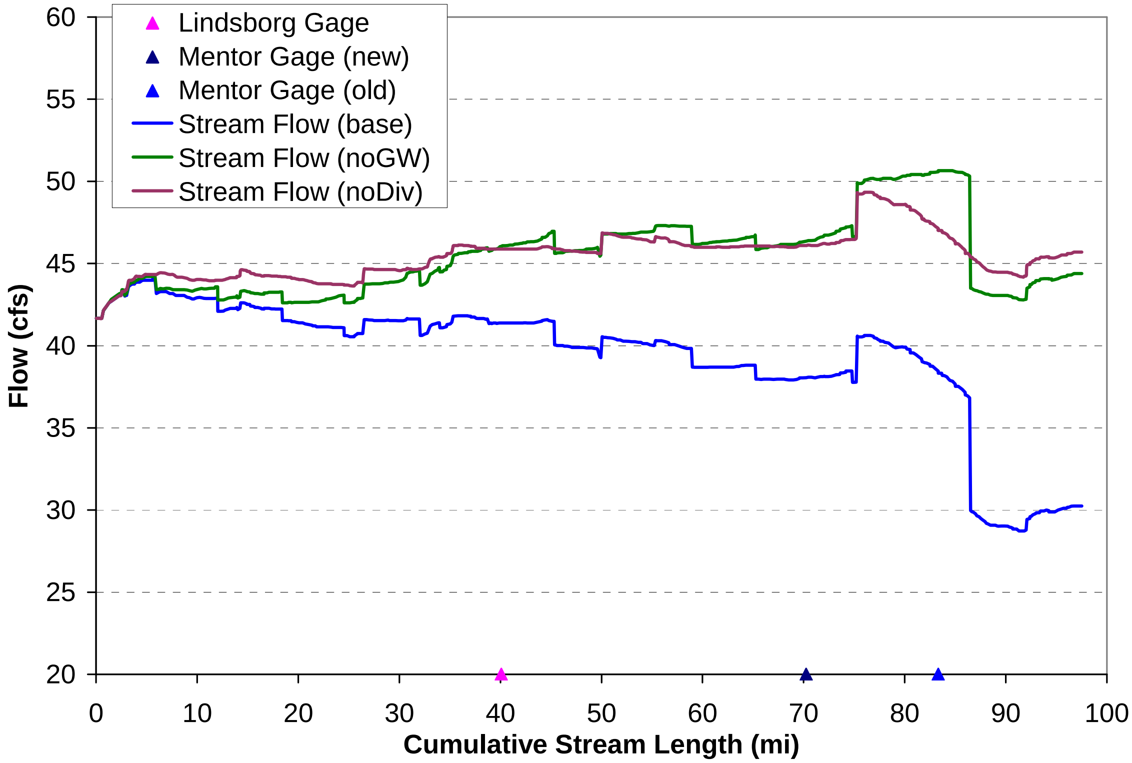

Figure 20- Average streamflow along the Smoky Hill River, summer 1955 (present-day conditions)

Table 11 Average Streamflow (cfs), Summer 1955 (present-day conditions)			
Location	**Base**	**NoGW (% from Base)**	**NoDiv (% from Base)**
Lindsborg Gage	41.4	46.0 (+11.28%)	45.9 (+10.86%)
Mentor Gage (new)	38.1	46.4 (+21.79%)	46.1 (+21.14%)
Mentor Gage (old)	38.3	50.7 (+32.16%)	47.0 (+22.65%)
End of Model	30.2	44.4 (+46.75%)	45.7 (+51.08%)

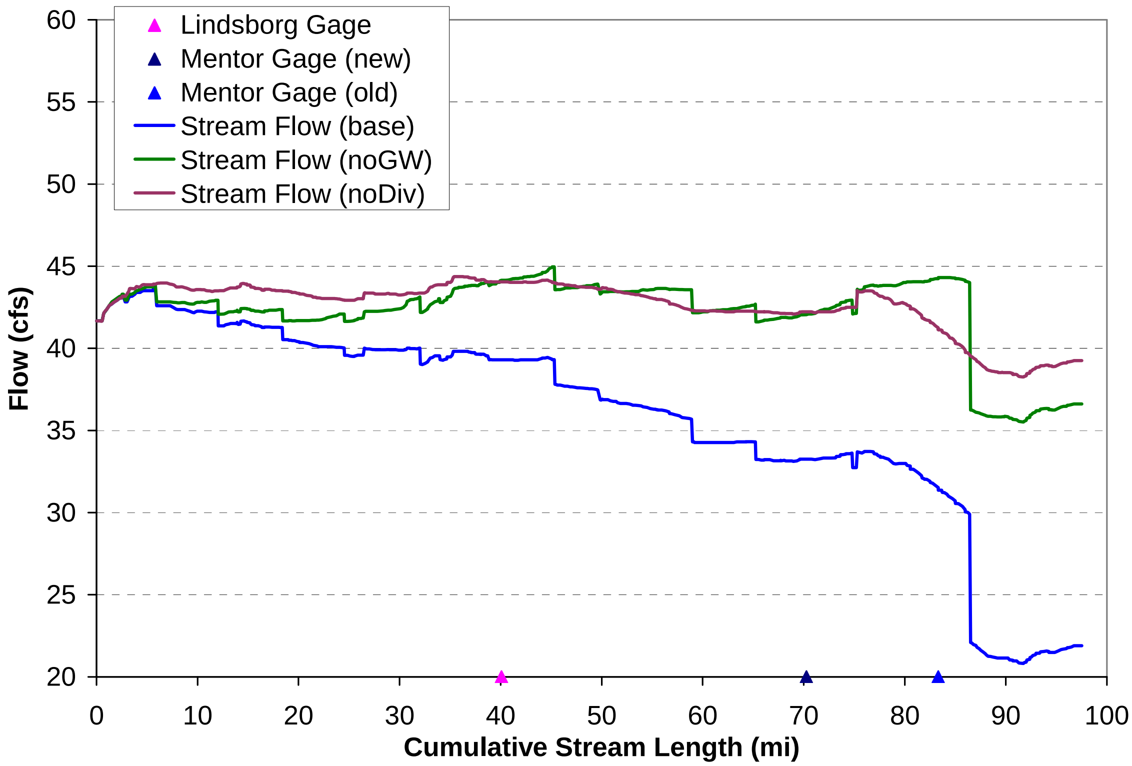

Figure 21- Average streamflow along the Smoky Hill River, summer 1956 (present-day conditions)

Table 12 Average Streamflow (cfs), Summer 1956 (present-day conditions)			
Location	**Base**	**NoGW (% from Base)**	**NoDiv (% from Base)**
Lindsborg Gage	39.3	44.1 (+12.32%)	44.0 (+12.08%)
Mentor Gage (new)	33.3	42.1 (+26.45%)	42.2 (+26.97%)
Mentor Gage (old)	31.4	44.3 (+41.27%)	41.1 (+31.12%)
End of Model	21.9	36.6 (+67.22%)	39.3 (+79.30%)

Figures 22 to 25 display the single-year stream-aquifer interactions from 1953 to 1956, respectively, under present-day conditions. Like the averages over the four-year time period, the no ground-water pumping scenario in each single-year shows the river will gain water from the aquifer via baseflow contributions. Likewise, in each year there is a gradual decline in net baseflow starting around Lindsborg when ground-water pumping is in place. This is followed by a slight rise near the Mentor diversion works (between the old and new mentor gages) and then a notable decline around Salina.

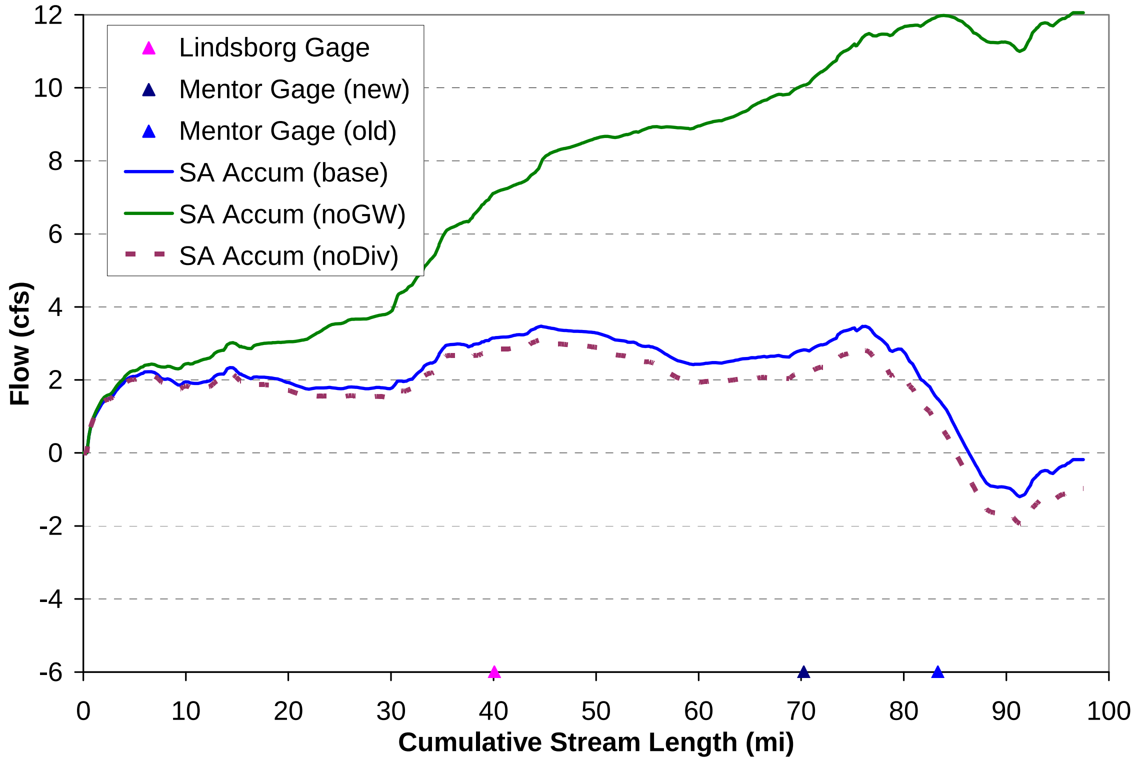

Figure 22- Cumulative stream-aquifer interactions along the Smoky Hill River, summer 1953 (present-day conditions)

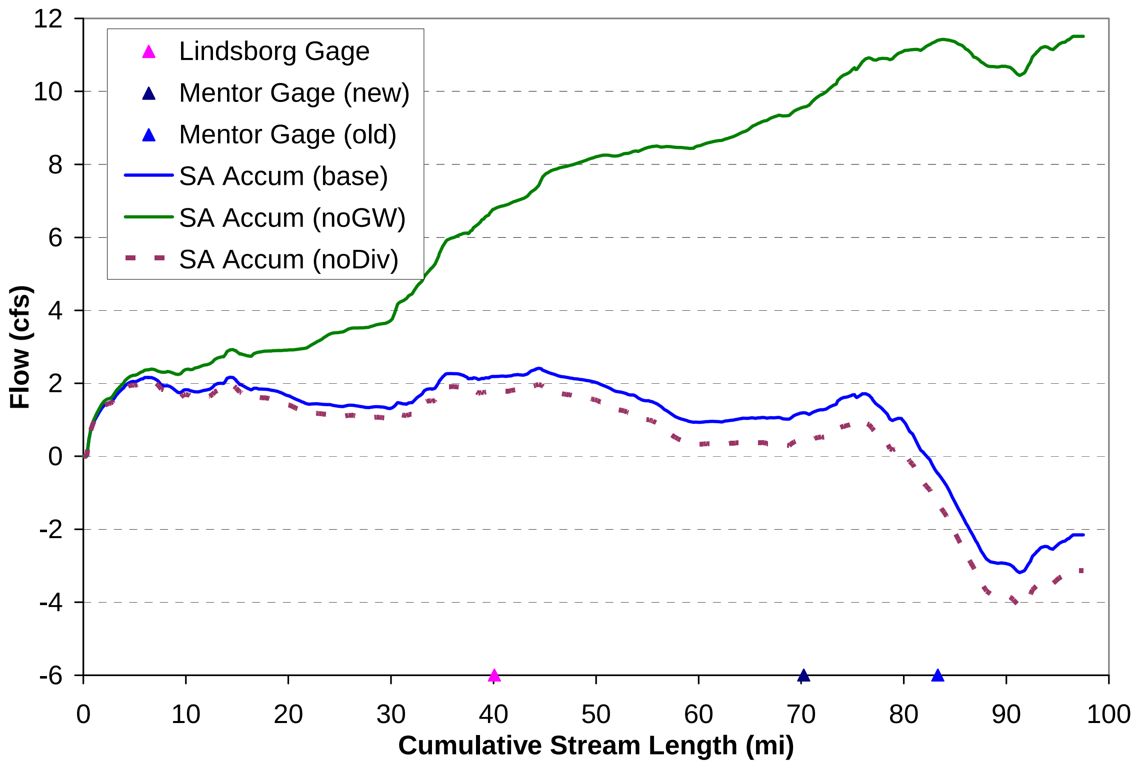

Figure 23- Cumulative stream-aquifer interactions along the Smoky Hill River, summer 1954 (present-day conditions)

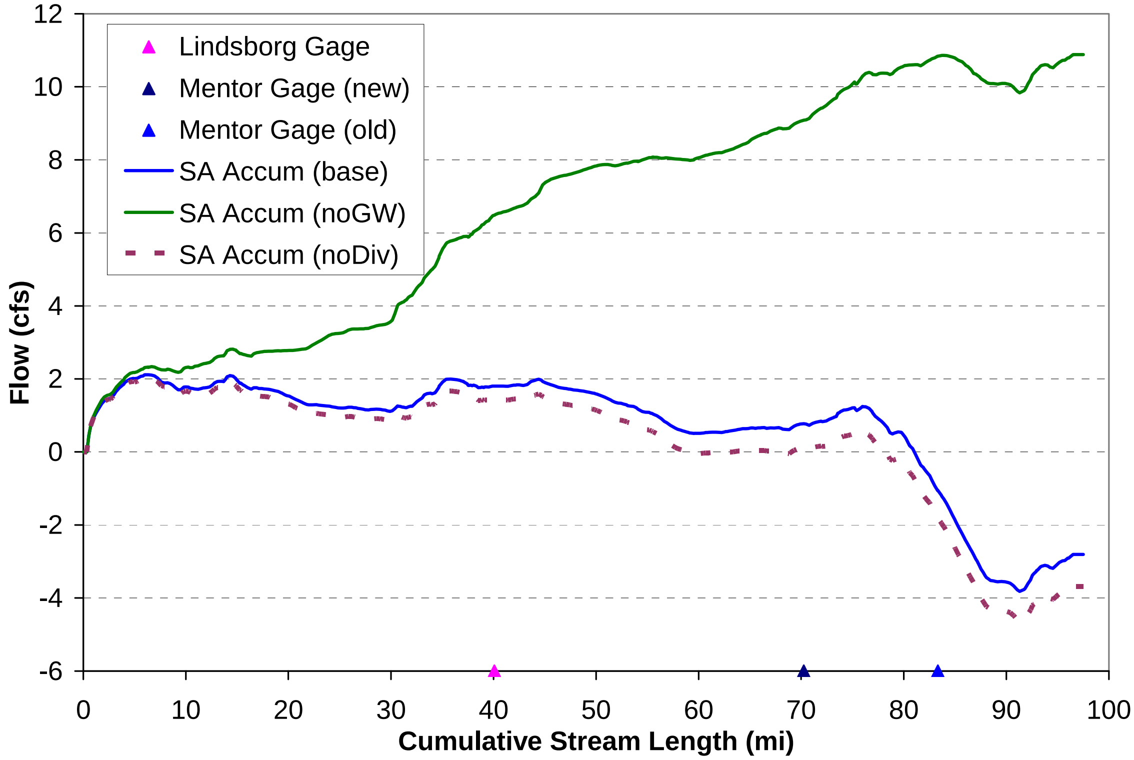

Figure 24- Cumulative stream-aquifer interactions along the Smoky Hill River, summer 1955 (present-day conditions)

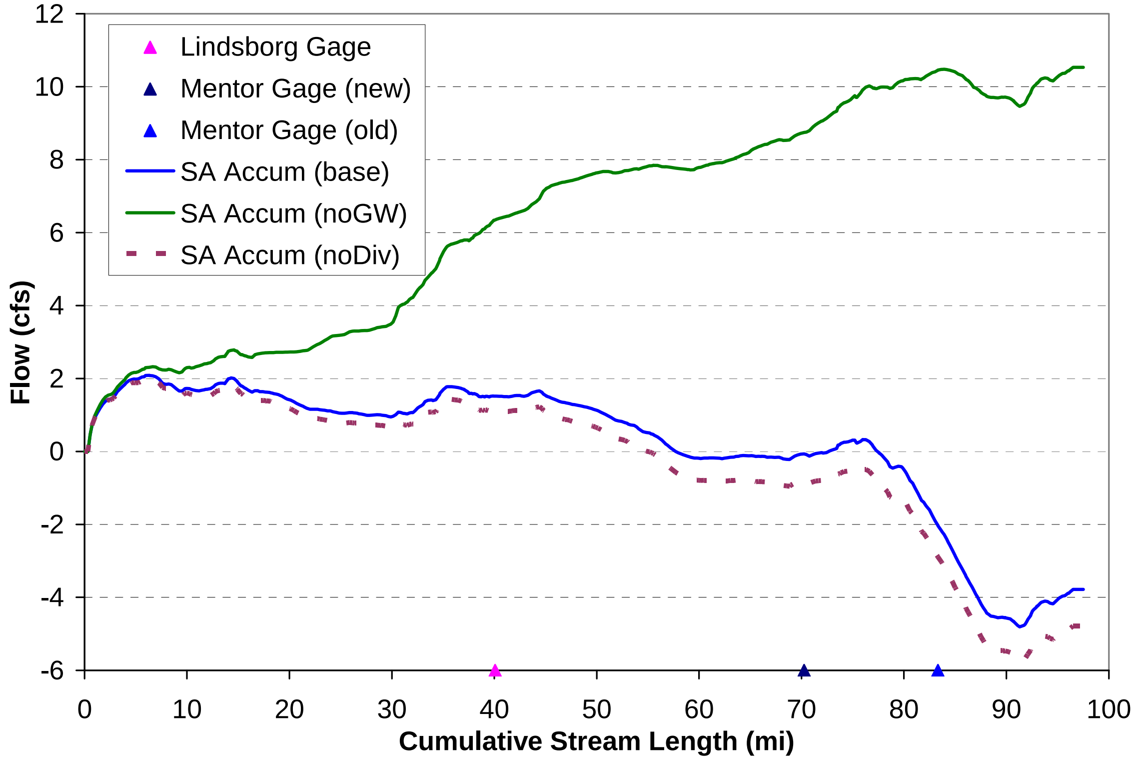

Figure 25- Cumulative stream-aquifer interactions along the Smoky Hill River, summer 1956 (present-day conditions)

In the 1953 and 1954 model runs, the stream-aquifer interactions curve for the base and no surface-water pumping scenario crosses the zero line near the old Mentor gage, indicating that the overall net baseflow is negative. In 1955 and 1956 (two of the driest consecutive years over the entire modeling period) the stream-aquifer interactions curve crosses the zero line further upstream near an area just south of Assaria (approximately 2 miles south of the new Mentor gage). In the 1953 and 1954 runs, this same area came close to a net gain of zero but still maintained some level of positive net baseflow contributions.

Addendum Conclusions

The additional model runs for evaluating streamflow in the Smoky Hill River using average 1953-1956 climatic conditions and present-day water-use showed a very small increase in flow along most of the river until Salina if either ground- or surface water pumping were stopped. Curtailing diversions from either water source resulted in accumulated streamflow that is higher than the base run (both diversion types in place) by around 4 cfs near Lindsborg to roughly 12 cfs to where the river leaves the model area. The percentage increase above the base condition ranged from approximately 11 percent near Lindsborg to 58 percent at the model end. Much of this separation occurs towards the end of the model area where Salina's large, senior water rights are in place.

Individual year results in the model from 1953 to 1956 under present day water-use showed similar patterns; 1956 (the driest year on record) displayed the largest percentage impact if either ground- or surface- water pumping was stopped. Overall, eliminating ground- or surface-diversions under these climatic conditions causes streamflow in the river between Lindsborg and Salina to remain fairly stable with only small rises or deceases that are generally under 3 cfs. With 1956 conditions, however, a slight declining trend in accumulated flow over this same river stretch exists even if only either ground- or surface-water diversions were stopped.

The stream-aquifer interactions assessment found that the no ground-water pumping scenario allows the river to gain water from the underlying aquifer in the form of baseflow. The ground-water diversion only scenario generally reduced this interaction such that baseflow gradually declines from Lindsborg to Salina. In the Salina area declines in baseflow significantly increases as the river becomes a pronounced losing stream with water infiltrating from the river into the aquifer. Single year scenario runs show the point at which the stream-aquifer interaction changes from net baseflow gain to river loss moves upstream from south of Salina in 1953 and 1954 to just south of Assaria in 1955 and 1956, the two driest consecutive years over the model period.

Actual reported ground- and surface-water pumping during the drought period of 2002-2006 and the simulated pumping of present day conditions over the drought period of 1953-1956 show varying levels of influence on flows in the Smoky Hill River. In all cases, stopping either all ground- or surface-water diversions will increase streamflow in the river relative to the impact of combined diversions. Under the driest conditions (1953 to 1956), the absolute increase in flow ranges from about 13 to 17 cfs by the time the river leaves the model area, which is roughly 50 percent of the flow in the base model runs (from 38 to 79 percent depending on the year).

In terms of the stream-aquifer interactions, the general trend during the 2002 to 2006 period (based on actual reported ground- and surface-water reports) was for a reduction in baseflow contributions from the aquifer to the river as a result of ground-water pumping. The river, however, was still primarily a gaining stream until it reached Salina. A repeat of drought conditions from 1953 to 1956 with projected present day water-use resulted in ground-water pumping reducing the baseflow contributions to a point where the river becomes a losing stream generally starting around the Lindsborg area. The overall flow in the river, however, remains fairly stable with small increases and decreases, generally 3 cfs or less, occurring along various river segments in the model.

It is important to note the numerical model simulates ground- and surface-water components based on 6-month time steps. There are undoubtedly times (days, weeks, or even months) within single time step intervals with below normal precipitation levels when the impacts of ground- and surface-water diversions on river flow can be much more substantial than the six-month average. Regardless, the model does indicate that extended periods of drought conditions can exacerbate the impact on streamflow by ground- and surface- water diversions as antecedent conditions start to build.

References

Wilson, B.B., Liu, G.L, Whittemore, D.O., Butler, J.J., 2008, Smoky Hill River Valley Ground-water Model. Kansas Geological Survey Open-file Report 2008-20, 131 p.