Model Questions

1. Conservation (1 d and e answered first)

a. (d) What is the estimated depletion of the stream in the Republican River Basin that is caused by conservation?

By conservation activities we assume you mean such farming practices as installing farm ponds and terraces and using minimum tillage and modern crop practices. The impact of these practices are not currently well understood. The Republican River Compact Administration Conservation Committee is conducting a study of the effects of terraces and small ponds. The Principle Investigators for the study are Derrel Martin of the University of Nebraska and James Koelliker of Kansas State University.

Preliminary results suggest that modern cropping and tilling practices are the primary cause of decreased runoff over the past fifty years; the effect of modern crop management may be 10 times that of terraces. Combined with modern crop management practices, terraces reduce runoff from the field to almost zero.

However, the modeling also shows that most of the water lost to runoff is not lost to evaporation, but instead recharges the aquifer. This would simply cause a retiming of, not a decrease in, streamflow.

b. (e) Does the amount of conservation vary from State to State as a percent of each watershed?

The only information available on distribution of conservation measures is for terraces. The inventory completed by the Compact conservation study shows a total of about 2.3 million acres of terraced fields in the Republican River Basin. Of these, approximately 220 thousand are in Colorado, 900 thousand are in Kansas, and 1.2 million are in Nebraska. Thus the largest impact from terraces on stream flow is likely to be in Nebraska.

The Republican River Compact Administration (RRCA) Engineering committee is in the process of creating an inventory of dams and small reservoirs that need to be tracked according to the Final Settlement Stipulation. This inventory is nearly complete for Nebraska, but not for Colorado or Kansas.

c. (a) Are the effects of conservation in the Model?

Yes and No. First it must be recognized that the RRCA groundwater model only models groundwater flow. The model does not include a surface water runoff component, and therefore any impact of conservation practices on surface water runoff are not explicitly in the model. If conservation measures have an effect on total streamflow through a change in runoff, it would be impossible for the groundwater model to account for this. To account for this impact, a separate rainfall model would be needed.

The conservation effects are not an explicit input into the model. However, the effects of conservation are implicitly taken into account due to model calibration. Although, there are no inputs to the groundwater model that specifically represent conservation measures, the model is calibrated to observed heads and baseflows. If conservation measures have had an effect on groundwater levels and stream baseflows, the model does account for this but it does not assign the impact to any specific factor

d. (b) If not, why were they excluded?

As stated in the answer to 1(d), at the time of the Final Settlement Stipulation (FSS), there was a lack of data regarding the effect conservation measures have on recharge to the aquifer, as well as the spatial and temporal distribution of conservation measures in the basin. Therefore, the RRCA Conservation Committee was created in order to answer these types of questions. The Conservation Committee provides an annual report to the RRCA.

e. (c) If the effects of conservation were in the Model, would it change the depletions to the stream that the Model says are caused by groundwater irrigation?

It is possible that specifically factoring in the change in recharge to the aquifer in locations where conservation measures have been implemented would change the model-calculated depletions in stream baseflow due to groundwater pumping. However, as indicated in the response to 1a, the currently used method for distributing recharge in the model provides for simulated baseflows and water levels that reasonably match observations. The method of distributing recharge could be changed to incorporate the effect of conservation measures on recharge, if a method could be devised that results in a match of model-predicted and observed baseflows and water levels that is at least as good as the current calibration does. However, it is very difficult to predict what type of effect this would have on the resulting model-calculated stream depletions due to groundwater pumping, if any. The difference in depletions would likely vary both spatially and temporally, and be both greater and less than depletions calculated with the model as currently used over space and time. It also must be noted that conservation practices, particularly the use of minimum tillage practices, reduce the need for supplemental irrigation, and therefore reduce the need for groundwater pumping. This reduction reduces Nebraska's consumptive use from irrigation and helps in Compact compliance. The net difference for the basin as a whole may or may not be significant.

2. Vegetation

a. Does the Model show a change in the amount of water used by riparian vegetation each year or each decade? Has there been an increase in vegetation water usage in the Model since the 1950s? If so, how much has the change been?

The model does show a change in riparian evapotranspiration (ET), both on a year to year basis and over the long term. A monthly maximum ET for every model cell is calculated each year based on climate data collected at three stations (McCook, Akron, and Red Cloud). This results in short term (monthly to annual) variability in the riparian ET in the model. There is also a long term trend in the total riparian ET in the model. This reflects both the gradual re-emergence of phreatophytes in the basin following the 1935 flood (increase in total annual ET with time) and the build-up of groundwater pumping (decreasing total annual ET with time). The re-emergence of phreatophytes is dealt with in the model by a series of sub-basin ET area factors (see http://www.republicanrivercompact.org/v12p/html/factors.html). These curves adjust the present day distribution of ET areas, mostly downward as one moves back in time toward 1935, to account for the gradual increase in phreatophytes from then until the present day. As groundwater pumping developed in the basin, the water extracted for irrigation came from several sources, including reduced riparian ET (this is known as ET salvage). Because of this phenomenon, riparian ET in the model during 2001 to 2005 is less than it was during the 1950's (average of approximately 500 kAF per year in the 1950's to approximately 420 kAF per year in 2001-2005).

b. What does the Model show consumptive use by vegetation to have been in 1920, 1960, and 2006?

   The following values are presented as multiyear averages in order to smooth out the short term variability and highlight the long term variability. The values are for the entire model domain, not just for Nebraska. In the 1920's, average annual riparian ET was approximately 480 kAF in the model. In the 1960's this had increased to approximately 540 kAF in the model. For the years 2001-2005 (the 2006 model run has not been finalized) the average annual riparian ET was approximately 420 kAF in the model.

c. Does the Model show vegetation water usage to vary depending on how much water is pumped by irrigation wells?

   Yes, ET decreases when streamflow decreases, because the water is not as available to the plants. This is a primary reason that riparian ET is so much lower in 2001-2005 when compared to the 1960's. The recent drought has also contributed to the lower riparian ET values. However, even during the 1990's, average annual riparian ET was approximately 470 kAF, significantly lower than during the 1960's despite the wet conditions.

3. Stream / Aquifer Relationship

a. Once a stream permanently stops flowing, it is said to have disconnected from the aquifer. According to the Model, do irrigation wells "above" a disconnected stream affect stream flow? Is it easier for Nebraska to comply with the Kansas agreement if the streams are dry?

The groundwater computed beneficial consumptive use is calculated by running the model under two scenarios, with groundwater pumping on and with groundwater pumping off. Any stream that is flowing with groundwater pumping off can potentially be impacted when the groundwater wells are turned on. If groundwater pumping causes an otherwise wet stream to go dry, it is obviously affecting stream flow. The accounting will calculate the difference between the streamflow with the pumping turned off and the streamflow with the pumping turned on. This is the stream impact value that will be used in the accounting.

It is therefore not easier for Nebraska to comply with the Compact if the streams are dry. The annual accounting to determine the computed water supply (of which Nebraska can consumptively use approximately half) essentially contains two components, gauged streamflows and consumptive use (both surface and groundwater). If Nebraska's streams were dry (i.e. virtually zero streamflow at the stream gauges) then the only component of virgin water supply in Nebraska would be the consumptive use. Put another way, Nebraska's consumptive use would be 100% of the water supply within Nebraska. Under the Compact Nebraska is not allowed to use 100% of the water supply within Nebraska. Dry streams always make it harder for Nebraska to comply with the Compact because less water flows into Kansas. Finally, dry streams would result in no Imported Water Supply Credit since that is based on the mound water measured at the stream gauges.

b. What is the relationship of the aquifer level to the stream flow? If the aquifer goes down, does the stream flow also go down? If the aquifer level stays level, does the stream also stay the same?

In the groundwater model, every stream cell contains a stream bed elevation. The model also calculates the stage in the river for that cell if there is any water in the river at that time. Then, if the aquifer level is greater than the stream stage, water will move from the aquifer to the stream. If the aquifer level is below the stream stage, water will move from the stream to the aquifer (until the stream dries up). The greater the difference between the aquifer level and stream stage, the more water will move between the aquifer and stream.

The rate of flow between the stream and aquifer is also dependant on the streambed conductance, a constant that is determined during calibration and never changes during future simulations. The streambed conductance is a property of the width and thickness of the streambed, the length of the stream in the model cell, and the hydraulic properties of the streambed (how readily water moves through the materials).

Large changes in aquifer levels are not required for the baseflows to the stream to change significantly. Typical values for streambed conductance in the Republican mainstem are approximately 1 ft^2/s (these values are lower in the tributaries due to narrower streams and finer streambed materials). This is multiplied by the water level difference to compute the flow between the aquifer and stream (e.g. a 1 foot water level difference would result in a baseflow of 1 ft^3/s for that model grid). The grid size in the Republican model is 1 mi^2, so baseflow to each model grid roughly represents the baseflow for each river mile. Therefore, a change in water levels of 1 foot would reduce baseflows (or increase stream losses) by about 1 ft^3/s (or ~724 ac-ft/yr) per river mile.

As an example, let's consider the Republican River mainstem in the Lower Republican NRD. The portion of the Republican River in the Lower Republican NRD is approximately 100 miles long. The LRNRD portion of the annual groundwater pumping impacts to streamflow has been approximately 45,000 acre-feet in recent years. Based on the numbers above, these impacts would occur with less than 1 foot of water level declines within Republican River stream cells in the LRNRD.

4. Precipitation

a. What percent of normal has precipitation been in the Republican River Basin each year for the last decade?

This would obviously depend on what is meant by *normal*. We will assume that normal is referring to the long term average (and not the more recent, above average rains of the 1980's and 1990's). The following table presents the percentile (the 50^{th} percentile is the median value, which for precipitation data is usually very close to the mean) for annual rainfall based on the official compact gauges. Data are presented for the gauges in Nebraska only, and for all of the Compact gauges.

Year	NE Only	All Stations
1996	94%	93%
1997	54%	56%
1998	39%	53%
1999	69%	72%
2000	34%	29%
2001	63%	66%
2002	2%	3%
2003	33%	26%
2004	70%	71%
2005	48%	61%

b. Is precipitation the primary factor determining Nebraska's allocation? If so, what percentage of the allocation does precipitation contribute to the allocation as compared to base flow on a year-to-year basis? Is there a significant variation in this percentage each year?

Precipitation is the only source of the Compact Virgin Water Supply. Precipitation that reaches the stream, either through runoff or as baseflow, during the year that it fell, contributes to the NE allocation for that year. However, much of a given years precipitation (or lack of), will affect baseflow for many subsequent years. It appears that this question is really asking; how much of each year's allocation is the result of precipitation during that year, versus baseflows resulting from previous year's precipitation?

This is very difficult to assess. DNR is currently studying the baseflow and runoff patterns in the basin. Preliminary results suggest that most of the streams in the basin are baseflow-dominated most of the time. This would suggest that the allocation would depend heavily on previous year's precipitation. However, during any given heavy precipitation year (such as 1993), the majority of the streams in the basin were clearly runoff-dominated.

Simply put, during dry to moderate precipitation years, there is probably very little runoff contribution to streamflow, so the NE allocation would be much more dependant on base flow, which is in turn dependent on precipitation from past years. During wet years, runoff is more dominant, and the allocation is primarily determined by the precipitation from that year.

c. Does the Model use precipitation inputs from just the official gages, or does the system use input from other locations, such as the NERain project? Would the Model benefit from additional input and measurement locations?

   The model uses the official Compact gauges only. These gauges were selected after careful analysis of the data which they produce. It is possible that the model would benefit from additional precipitation stations, though stations with a short period of record are not very useful for model calibration.

5. Dams and Reservoirs

a. Has the placement of the dams in the Basin caused a change in base flow or stream flow?

   The construction of dams decreases peak flood flows. However, the overall effect cannot be known without completion of a calibrated rainfall-runoff model.

b. Has the construction of dams caused an increase in the number of trees in the Basin?

   There are studies that suggest that the decrease in high flows due to reservoir storage has been a factor in increasing riparian vegetation.

6. Model Inputs

a. Have there been any significant modifications to the data going into the Model since what was released to the public on the RRCA web site in 2005?

Specifically, has there been any revision of historical pumping data or any other changes? If so, please detail those changes.

There have been no significant changes to model input data for the model runs for 2005 and previous years. For 2006, DNR will be using the metered pumping data and certified acres collected by the LRNRD, MRNRD, and the portion of the TBNRD within the surface water basin. Pumping meter volumes and certified acres have been used as inputs to the groundwater model for the URNRD since 2001. For the previous years, the pumping in the LRNRD, MRNRD, and TBNRD was estimated using power records, and the groundwater irrigated acres stimated using National Agricultural Statisitics Service harvested irrigated acres. DNR will continue to calculate the power record estimated pumping, and compare this to pumping as measured by meters. At the current time there is not sufficient data to draw any conclusions regarding the power record method used in the past.

b. Are NRD pumping records used in the Model, or are power records used? What are the pros and cons of using each?

Power records were used in the model when metered pumping records were not available. Now that complete sets of metered pumping records are available for the portions of the LRNRD, MRNRD, and TBNRD lying within the surface water basin, these will be used in the model (metered data has been used since 2001 in the URNRD). The advantage of power record data is that it is available for years when no metered pumping records exist. However, it is an estimate rather than a direct measurement. Metered pumping records are the preferred source of pumping data as they are a direct measurement. However, these data is not available for every well in the basin for most of the period of time they have been in use. Power records will continue to be used to estimate pumping for those portions of the model outside of the Republican River Basin and wells that were pumped but have no metered volume available (e.g., broken meter).

c. What portion of the base flows used by the Model occur within 20 days of a precipitation event?

There are no precipitation "events" in the model. A groundwater model does not use precipitation as a direct input. The Republican model takes the annual precipitation data for the official gauges and interpolates these values to every model grid cell. Then a series of curves are used to determine the recharge to that cell, based on the precipitation, the soil type, and whether or not the cell is irrigated. The Republican model uses monthly stress periods, meaning the stresses (e.g. recharge, pumping) can only be changed on a monthly basis. The annual recharge for each cell is apportioned to each monthly stress period using a fixed monthly distribution. See http://www.republicanrivercompact.org/v12p/html/ch04.html for more information. A more detailed model would be needed to simulate groundwater flow on a daily time scale.

7. **System Design**

   a. The Model used for the Republican River Basin uses 1 aquifer layer. The Platte River Model uses multiple levels. What are the resultant differences?

      It is very difficult to assess the impact of the multiple layers in the Platte River model because there are so many other differences between the two models. The Platte River model may yield different results for the Republican River tributaries in that model area, but this may have nothing to do with the multiple layers. Also, it is important to note that the Republican River is simply a boundary condition to the Platte River model. The focus of the Platte River model is on the Platte River; therefore, much less attention was given to the area of the Republican River in the Platte River model.

   b. There is a significant amount of overlap between the Platte and Republican Models. Has there been a comparison between the two Models? Do the two Models show similar results? What end result differences are there?

      DNR is currently conducting a study to compare the inputs to the two models in the area in which they overlap. While there are numerous, small scale and minor variability's in the model parameters, there do not appear to be any significant differences. The analysis of the model results (e.g. predicted heads and baseflows) is not complete at this time.

   c. If water is imported into the Basin via Spring Creek, where is it measured at?

      The first Compact gauge below Spring Creek is at Guide Rock.

   d. What is the difference in credit to Nebraska if the stream is augmented from outside the Republican River Basin as compared to from within?

      If water is imported from outside the basin, we will be credited with 100% of the water that reaches stream.

8. **Mound**

   a. The mound credit Nebraska has received each year from the Platte has decreased? Is this because of a decrease in the amount of water coming from the Platte, or is it because more water is failing to get to the stream once it is in the Republican River Basin? If it is the latter, is it drought, pumping, or conservation that is causing the problem? If a combination, what are the percentages attributed to each cause?

      The mound credit has been reduced from nearly 20 kAF in 2000 to less than 10 kAF in 2003, though it has increased slightly since then. Our analysis of our contribution of mound water to the Republican River indicates that the water coming from the Platte River has only decreased. The problem is that the water that gets into the basin is not reaching the stream. This is primarily due to ground water pumping in the Tri-Basin and Lower Republican natural resources districts. To a much lesser extant, the reduction in recharge during the recent drought has also prevented mound water from making it to accounting points in the stream.

b. If the amount of mound water coming from the Platte is increased, will it be easier for Nebraska to stay in compliance? How can Nebraska increase this credit, according to the Model?

An increase in imported water supply reaching the compact gauges would make it easier for NE to stay in compliance because the Mound Credit would increase. This could happen in two ways. A significant increase in the amount of surface water-induced recharge in the area of the mound would increase the amount of mound water reaching the stream. However, this could take a significant amount of time to cause any appreciable change, as the mound has formed over many decades and groundwater movement is generally very slow. Alternatively, a reduction in pumping in the area of the mound (and the areas between the mound and the river) would allow more of the mound water to reach the stream, increasing the mound credit. The faster way to increase the mound credit would be to limit pumping.

9. Surface Water

a. Is there any surface water still available to purchase in the Republican River Basin? If so, how much is there and who owes it?

There is no significant source of additional surface water in the basin. Existing water rights may be available for dry-year leasing on an occasional basis.

b. What are the effects on the Model when surface water is put in the stream instead of the canals and fields?

Recharge to the aquifer from canal seepage and surface water irrigation is a significant input of water to the model. When less water is used for surface water irrigation, there will be less recharge in the model. This has the potential to increase the model calculated impact to streamflow.