ESPA GROUND WATER MODEL
DEVELOPMENT OF RIVER RESPONSE COEFFICIENTS

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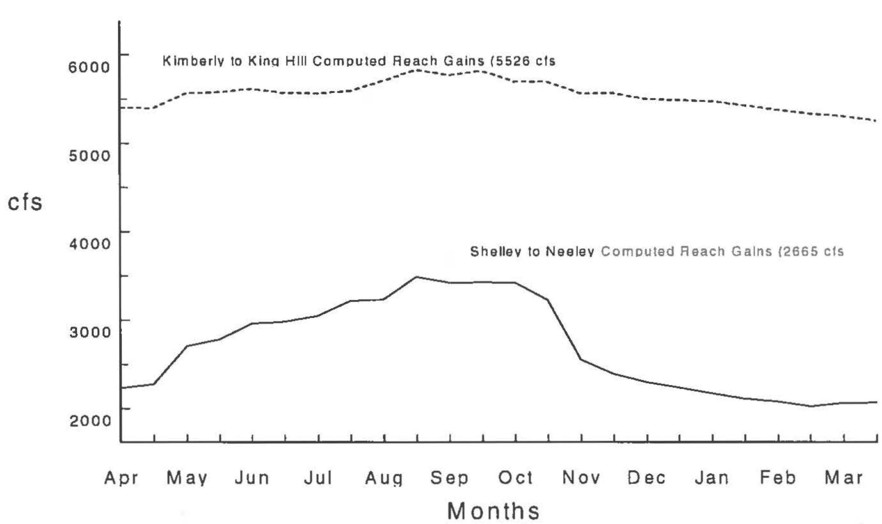
Model Calibration

The Idaho Department of Water Resources (IDWR) and University of Idaho (U of I) ground water model was calibrated to spring/fall/spring target water levels using USGS RASA data from the year 1980. The 1980 estimated river gains/losses to the Snake River were also used as targets for calibration. Using two-week time steps, an inverse modeling procedure was used in which the model itself generated aquifer parameters such that a reasonable match was made with target values. Manual adjustments were made to the model generated parameters when these values appeared outside the bounds of known or reasonable values.

Base Condition

The base condition steady state run was then developed by replacing the 1980 estimates of recharge/discharge with 1992 estimates or, in some cases, an average of a period of years preceding 1992, such as 1983 through 1992, during which conditions remained relatively stable. The base study then represents a "present level" condition by repeatedly running the base data until a steady state condition is reached. At the steady state condition, aquifer change in storage, as well as water levels and river gains, do not change significantly on an annual basis. Figure 1 shows an example of the river gains output from the base simulation.

Figure 1. ESPA Aquifer Discharge for Initial Base Simulation, Year 58



Model Use

To evaluate the effect of various "what if" scenarios, in which changes in recharge/discharge are introduced, the base condition model is run with the new stresses added to the model. This run is then compared to the base condition run to judge the effect, both in terms of ground water levels and river gains/losses.

Significant in this process is that absolute values of the results are generally reported, but not portrayed as likely to occur. The magnitude of the effects of any scenario is portrayed instead by *changes* in modeled water levels and river gains. The reason that absolute values resulting from a scenario cannot be reported as a condition that will occur and can be directly measured, is that in reality many other changes in recharge/discharge will also occur, or have occurred, which will simultaneously have their own impact on the aquifer. Figure 2 shows an example of the results of the study which determined the effect on reach gains after 25 years of ground water pumping on the ESPA. Results are shown throughout the year in terms of changes in gains rather than absolute gains.

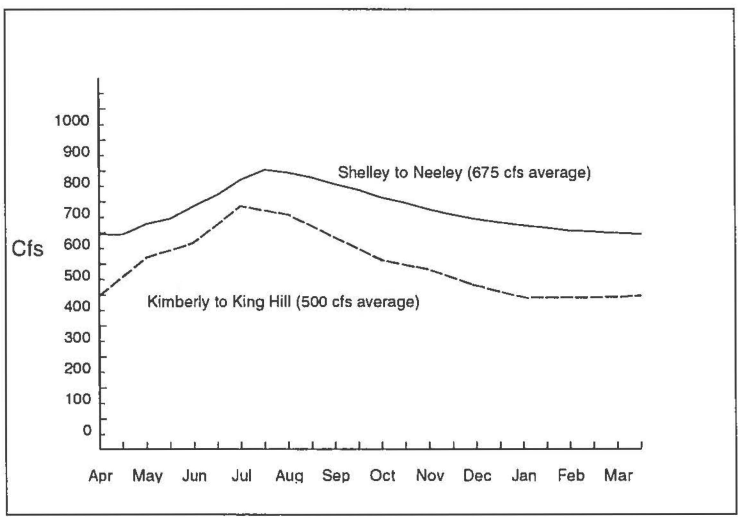


Figure 2. Changes in Reach Gains Resulting from Ground Water Pumping over ESPA after 25 years.

One of the primary uses of the IDWR/U of I ground water model is to determine the hydrologic effects of past and future ground water use for irrigation. The combined effect of all ground water irrigation was determined by identifying lands irrigated by ground water pumping and then adding the estimated consumptive use of these lands to the appropriate model locations as a recharge term. The model was then run in two-week time steps for several years using the same inputs for each year. In this manner the change in ground water levels and gains to the Snake River could be evaluated. Results of this study indicated that the combined effect of all ground water pumping as of 1992 was a decrease in gain to the Snake River from Shelley to Neeley of approximately 675 cfs and a 500 cfs decline from Kimberly to King Hill (see Figure 2).

To determine the effects on Snake River gains by specific areas, the modeled area was divided into approximately 20 zones having similar effects on river reaches. The acres irrigated from ground water in each of these zones were identified, and similar to the combined study described above, the estimated consumptive use was added back as a recharge term at the appropriate locations. For each of the zones, the model was then run for several years to a steady state condition to determine the effect on Snake River gains. These effects were converted to a unit response coefficient. For example, for a zone located immediately above American Falls Reservoir, one unit of ground water pumped for irrigation resulted in a 0.90 unit depletion to the Shelley to Neeley gain. For a zone located immediately above the Thousand Springs, one unit of ground water pumped resulted in a 0.98 unit depletion to the Kimberly to King Hill reach.

Model Accuracy

The reliability of modeled results is generally determined by the success of the modeler to achieve calibration. For the IDWR/U of I model, calibration was achieved by successfully recreating the aquifer water levels and river gains for the year 1980.

Confidence in the model would be increased by using the 1980 calibration to accurately predict conditions in other years or in a series of past years. The scarcity of measured data for both data input and result evaluation has prevented this from occurring. Major data deficiencies are encountered when estimating irrigated acreage, determining underflow from tributary valleys, and recreating accurate water level contours over the entire ESPA with limited water level measurements. The 1980 data was prepared under the intensive USGS RASA program, which provided a high level of funding and manpower commitment and resulted in comprehensive hydrologic data collection and analyses. The ground water model developed as a part of RASA also was calibrated solely on 1980 data.

River Gains and Losses

Of major importance in future ground water management programs in Idaho are river gain/loss response coefficients generated by the model. These coefficients can be used to determine the magnitude of the effect of ground water pumping on the gain/loss to the Snake River above and below Milner Dam. This above/ below Milner Dam distribution is significant in view of the fact that all inflows to the Snake River above Milner are entirely committed during parts of each year to natural flow rights that are administered by Water District 1.

The response of river gains and losses to ground water pumping determined using the IDWR/U of I model can be compared to similar studies performed by the USGS ground water model for the RASA program. The USGS model was used to try to simulate actual conditions from 1890 to 1980 with and without ground water pumping in a study very similar to that completed with the IDWR/U of I model. Figure 3 shows the results of these studies along with historic estimates for the Blackfoot to Neeley and Milner to King Hill reaches of the Snake River. The Blackfoot to Neeley reach shows relatively constant values for the period 1930 to 1980 for both the modeled (calibrated) gain and the measured gain. The Milner to King Hill reach shows a rising trend to the mid 1950's and then a slight decline to 1980 for modeled and measured gains. Although the USGS modeled and measured gains show the same pattern, in both reaches the modeled gains are overestimated.

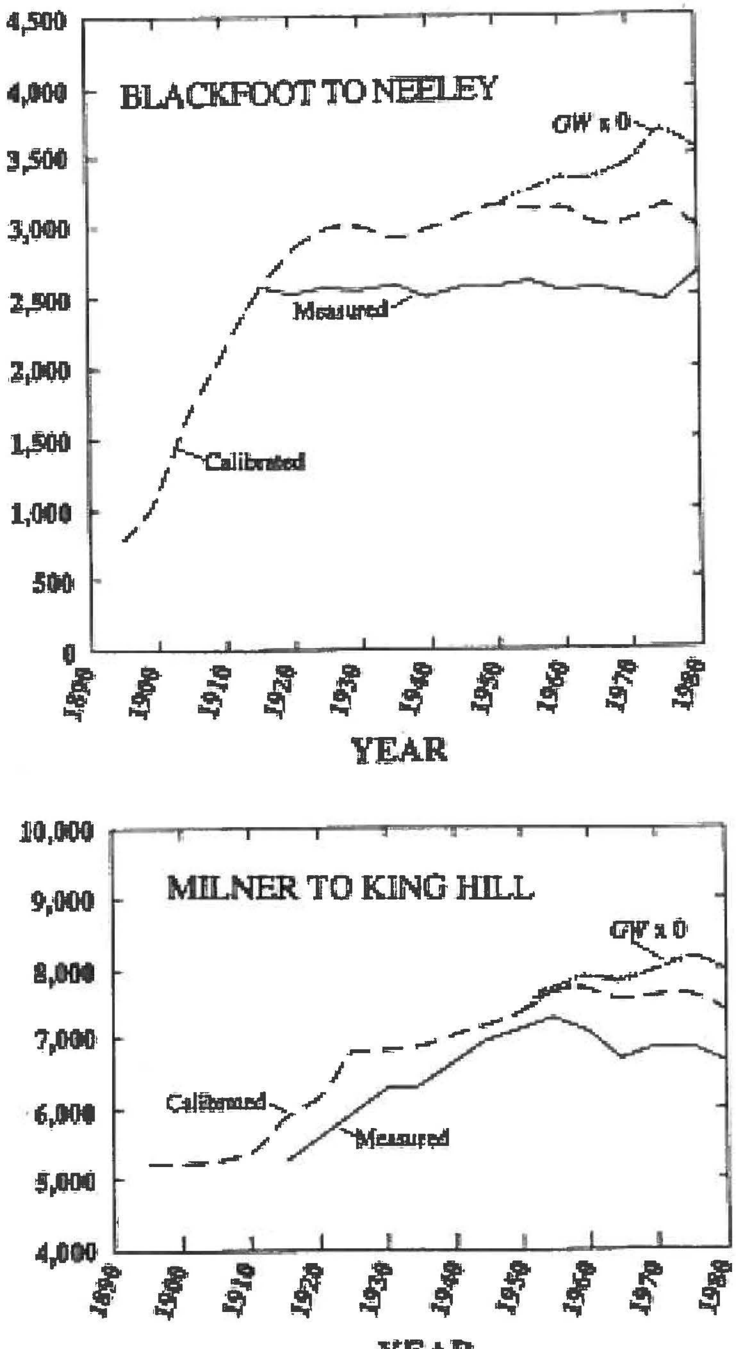


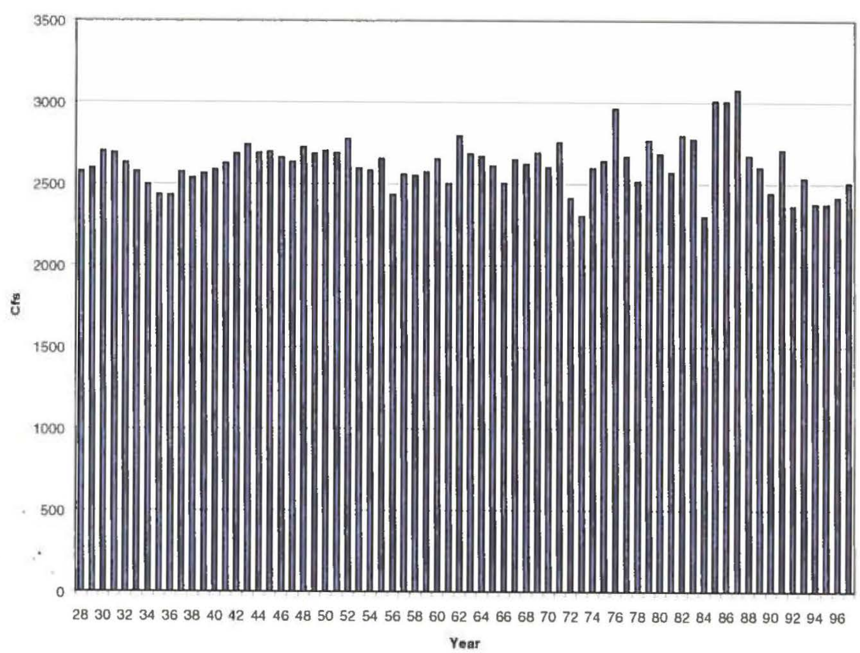
Figure 3. USGS RASA Transient Simulations – Reach Gains in Cfs

The effect of ground water pumping is shown in both reaches beginning in 1950. The modeled "without groundwater" USGS simulation indicates that the effects of pumping increased from 1950 to 1980 causing a reduction in gain to both reaches of approximately 600 cfs each by 1980. The 1992 simulated effect of "without ground water" by the IDWR/U of I model was 675 cfs from Shelley to Neeley and 500 cfs from Kimberly to King Hill. For direct comparison, the 1980 simulated effect computed by the

IDWR/U of I model was 555 cfs from Shelley to Neeley and 415 cfs from Kimberly to King Hill. The two models agree quite well for the above Neeley reach of the Snake River. The USGS model shows a greater effect on the below Milner reach, probably because the USGS model included the ground water irrigated area south of the Snake River east of Murtaugh Lake. This area is outside the IDWR/U of I modeled area.

The gains to the Snake River above Milner in the form of spring discharge are often represented by calculating the gain between the near Blackfoot stream gage and the Neeley stream gage. Figure 4 shows the 1928 through 1997 reach gain between these two gages. This gain has been consistently about 2600 cfs.

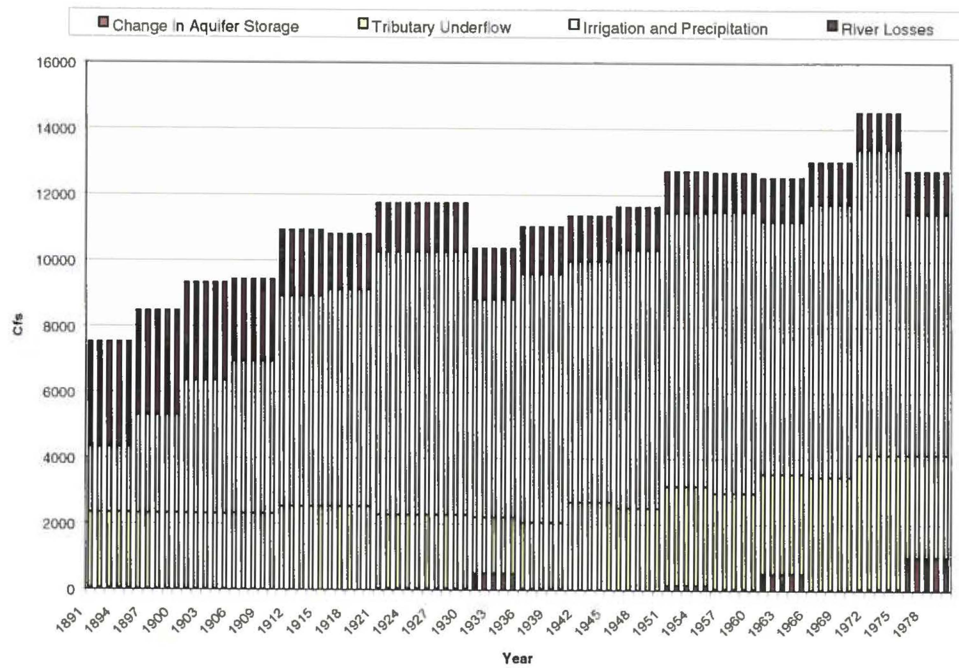
Figure 4. Average Annual Gain Snake River - Blackfoot to Neeley



Ground water pumping over the Eastern Snake Plain Aquifer began in the early 1950's and reached 90% of the present level of development by 1980. By 1980 ground water depletion over the plain had risen to about 2000 cfs. The magnitude of this depletion and the response functions for nearby areas irrigated from ground water would indicate that a portion of this depletion would be evident in the Blackfoot to Neeley gain, which has not been the case. The constant Blackfoot to Neeley reach gain in spite of the increase in ground water depletion can be attributed to two factors. First, the occurrence of extremely wet years over the Snake Plain in the 1970's was an offsetting factor at the time ground water pumping was increasing rapidly. Second, the hydraulically connected reach above American Falls may extend above the Blackfoot gage such that pumping effects are reflected in part in the Shelley to Blackfoot reach. In addition, a decreasing water table also induces losses in portions of the reach from Heise to Shelley.

Insight into the impact of the extremely wet years of the 1970's can be gained by examining the water budget prepared for the transient simulation for the USGS RASA study. In spite of the significant ground water pumping that had peaked by 1980, the simulated historic Blackfoot to Neeley gains did not show declines (see Figure 4). The total water supply estimated for the RASA study is shown in Figure 5. It is evident from this graph that overall water supply to the Snake Plain increased after 1950, coinciding with the time period when ground water pumping began. Major factors in this increase

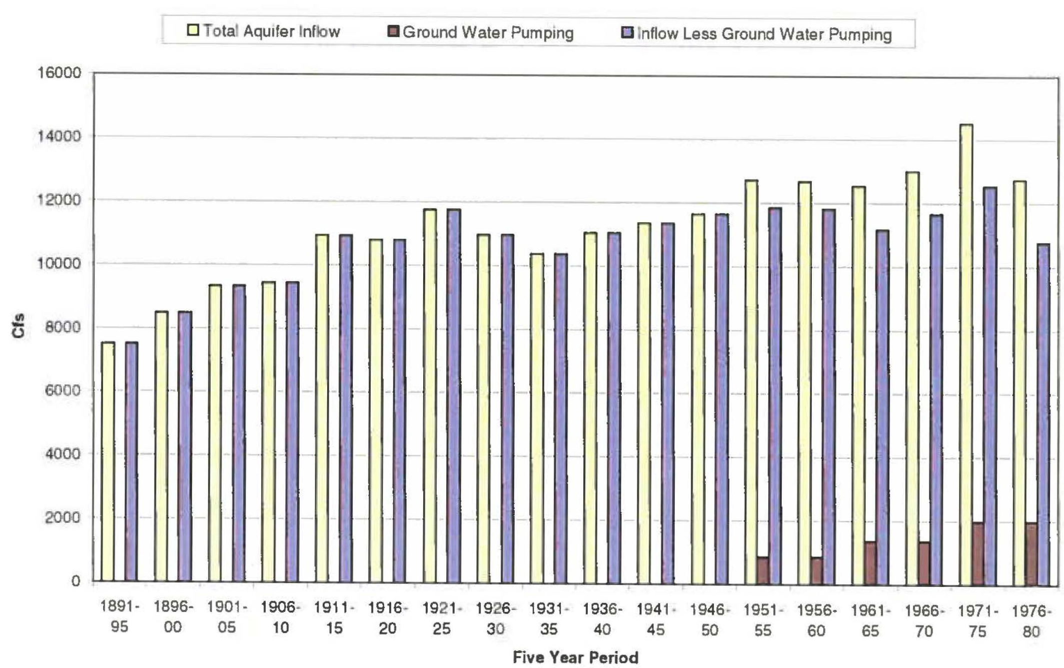
Figure 5. Total Inflow to ESPA - RASA



were greater tributary underflow, precipitation, and recharge from surface irrigation.

In Figure 6 the total water supply from Figure 5 is plotted along with the

Effect of Ground Water Pumping on Total ESPA Inflow - USGS RASA



estimated ground water pumping and the difference between the two. This difference represents the net water supply available after correcting for ground water pumping. This difference is plotted in Figure 7 along with the Blackfoot to Neeley gain. From

Figure 7. Comparison of ESPA Recharge (USGS RASA) with Blackfoot to Neeley Gain

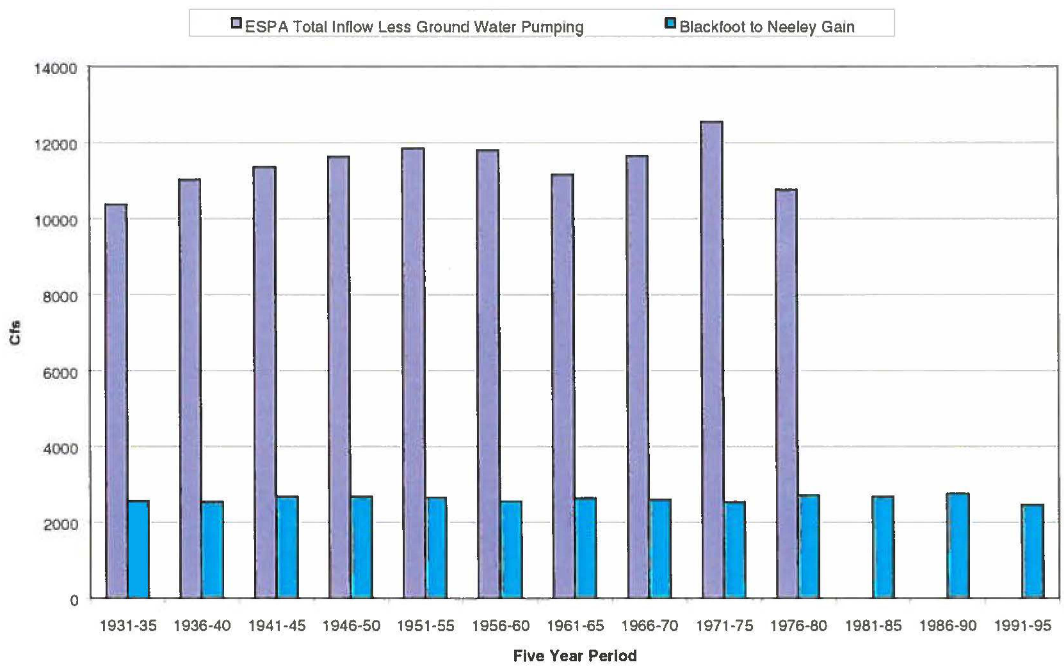
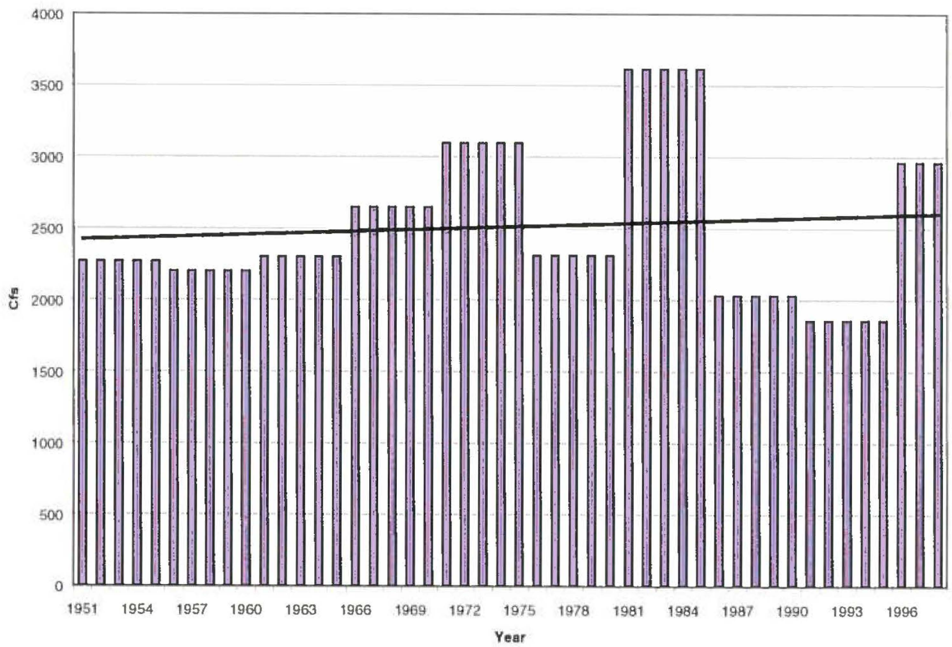


Figure 7 it can seen that the net water supply to the Snake Plain aquifer had not markedly decreased from 1950 to 1980 when ground water pumping was rapidly increasing.

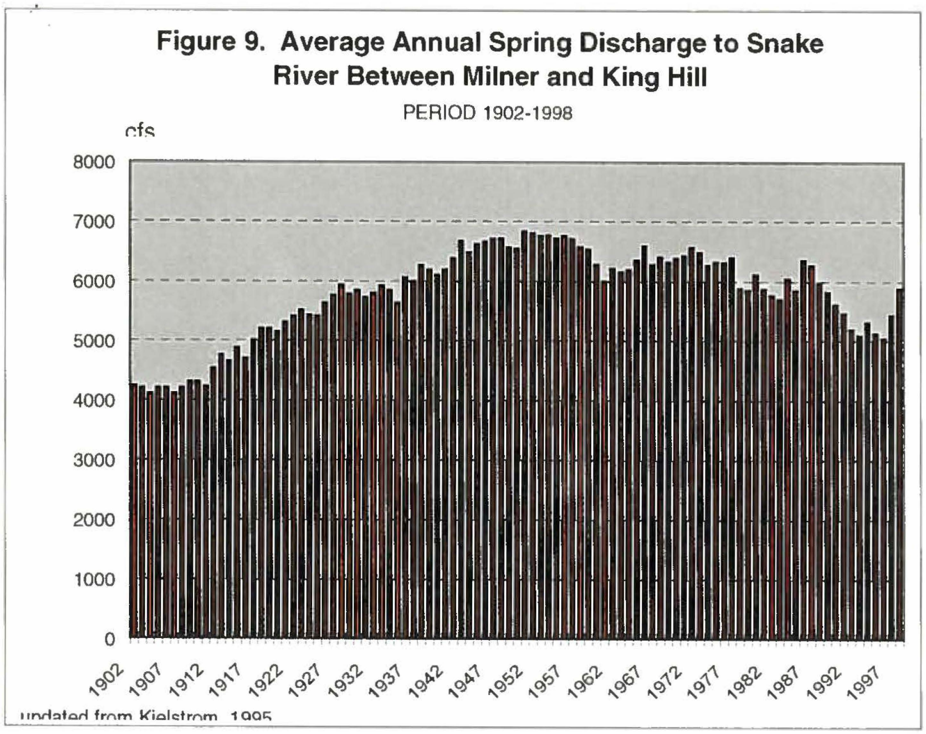
The USGS RASA study time period ended in 1980. The Blackfoot to Neeley gain is shown beyond 1980 in Figure 7 and shows that these gains are still relatively constant with only a slight downward trend in recent years. To assess post 1980 conditions the tributary underflow component of ESPA recharge was extended to 1998 using the same methods as were used for the RASA study. Figure 8 shows the tributary recharge from 1951 to 1998 resulting from this extension, along with a trend line for the data. These data show that the years immediately following 1980 were record high values, which more than compensate for the low water supply conditions in the late 1980's and early 1990's. Recent years again show tributary recharge as above average.

The mass balance values presented in Figures 5 through 8 are for the entire Snake Plain and do not take into account areal distribution. The composite water supply values include a variety of influences such as changes in irrigation methods that have occurred in concentrated areas and are not necessarily distributed evenly over the plain. Other factors may not be apparent when considering the entire plain because they are offsetting, but do have effects in specific areas. For example, unlike the Blackfoot to Neeley reach, other reaches in the USGS RASA study do show significant

Figure 9. Annual Tributary Recharge to ESPA - USGS RASA Method



changes over time in measured and modeled gains. From Figure 3, it can be seen that the Milner to King Hill measured and modeled reach gains increase until the mid 1950's and then begin to decrease to 1980. Figure 9 shows the estimated spring discharge between Milner and King Hill from 1902 through 1998 using a method developed by Kjelstrom of the USGS. Recent data (post 1980) show a general decrease in spring discharge with a possible recovery in the years following the 1987-1992 drought period.



The USGS RASA study also included measured and modeled gains in the Heise to Blackfoot reach. These gains are shown in Figure 10. As stated in the RASA study, "losses decreased in the reach Heise to near Blackfoot from 1912 to 1980 as a result of a rise in ground-water levels under surface water irrigated lands near the river." These

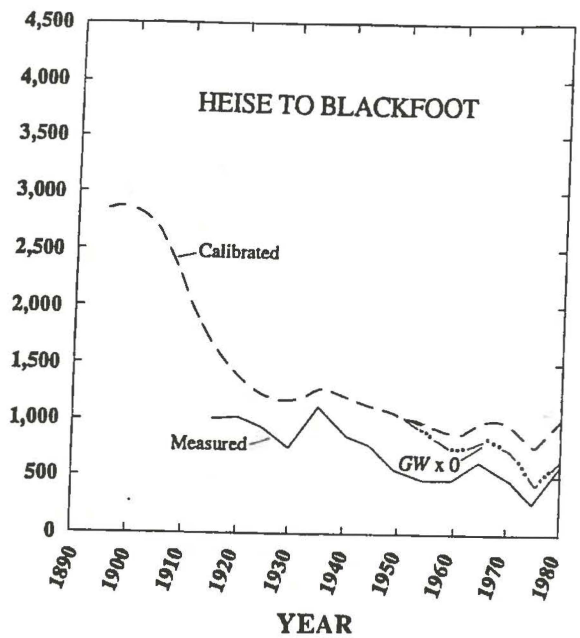
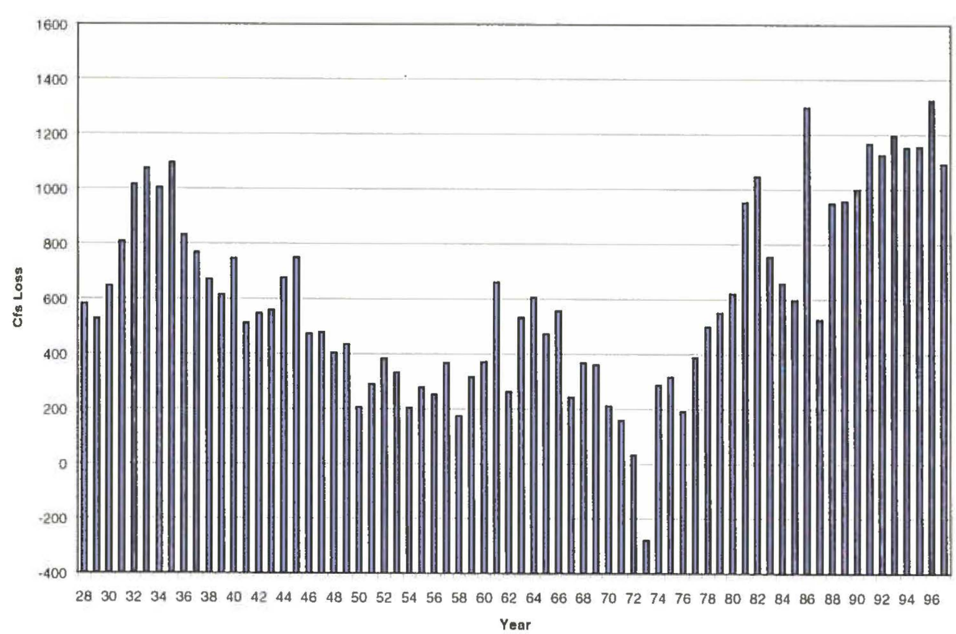


Figure 10. USGS RASA Transient Simulations – Reach Gains in Cfs

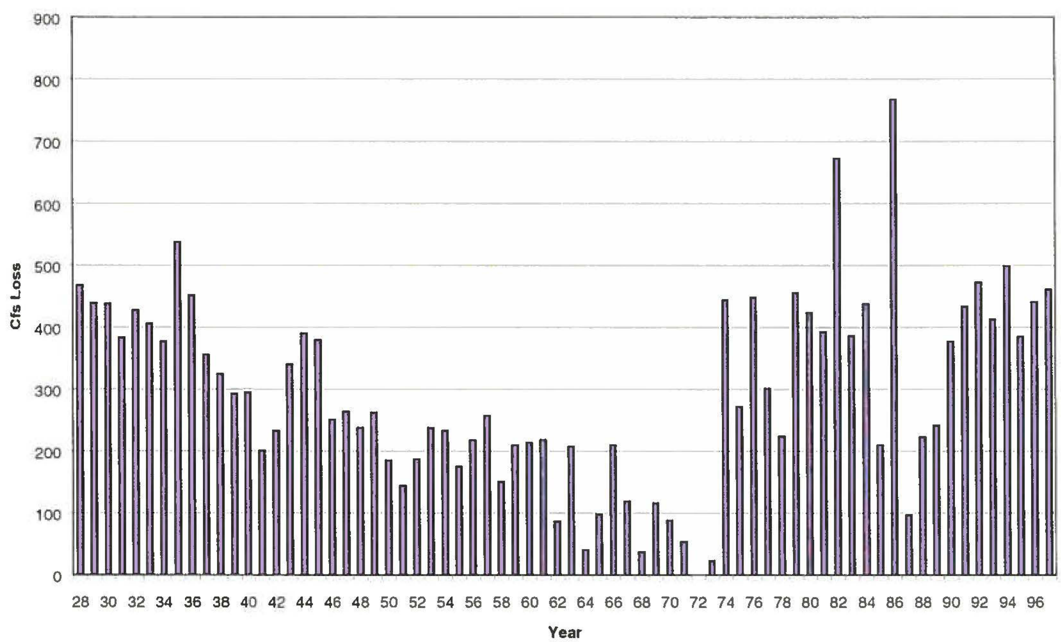
losses again began to increase subsequent to 1980. Figure 11 shows the 1928-97 Heise to Blackfoot unidentified gains. Recent increases in losses in this are most likely

Figure 11. Average Annual Reach Loss - Snake River Heise to Blackfoot



attributable to declines in the water table along this reach. Figure 12 shows the reach gain for the Shelley to Blackfoot reach. This reach shows the same pattern of declining loss until the early 1970's and then steadily increasing loss to present. This data supports the probability that ground water depletions, while not evident in the Blackfoot

Figure 12. Average Annual Loss - Snake River Shelley to Blackfoot



to Neeley gains, have had and likely do have an observable effect on the Shelley to Blackfoot reach, as well as the Heise to Shelley reach.

Insight into the ground water connectivity of the Snake River above the near Blackfoot gage can be gained by examining the water table and river channel elevations between the Shelley and Blackfoot gages. Figure 13 shows the 1980 spring and fall ground water elevations along this reach. From this graph it can be seen that the Snake River was perched approximately 70 feet above the water table at the Shelley gage. However, the fall water levels rise to lees than ten feet from the river bottom about 8 river miles below the gage, and remain within 30 feet or less for the remaining 25 miles to the near Blackfoot gage. In some locations the water table directly intersects the channel bottom. Therefore, it is likely that above American Falls gains and losses attributable to fluctuations in water table heads should include the reach Shelley to Blackfoot. In the USGS RASA study, water levels within 30 feet of the channel bottom were assumed to affect river gains.

Portions of the Snake River between American Falls and Milner are also considered head dependent in both the IDWR/U of I model and the USGS model. The unidentified gain for the entire reach of the Snake River from Heise to Milner is shown in Figure 14. Combining all reaches eliminates errors associated with errors in gaging both at the intervening stream gages and at American Falls and Lake Walcott reservoirs. This gain shows a pattern very similar to the gains from Milner to King Hill as shown in Figure 15. Both reaches show a low period in the 1930's followed by a gradually increasing gain to the 1950's. Gains dropped off somewhat in the early 1960's, rose in the mid 1970's, and generally then declined to present (1990's).

Figure 13. Snake River Ground Water and River Channel Elevations Between Gaging Stations near Shelley and near Blackfoot

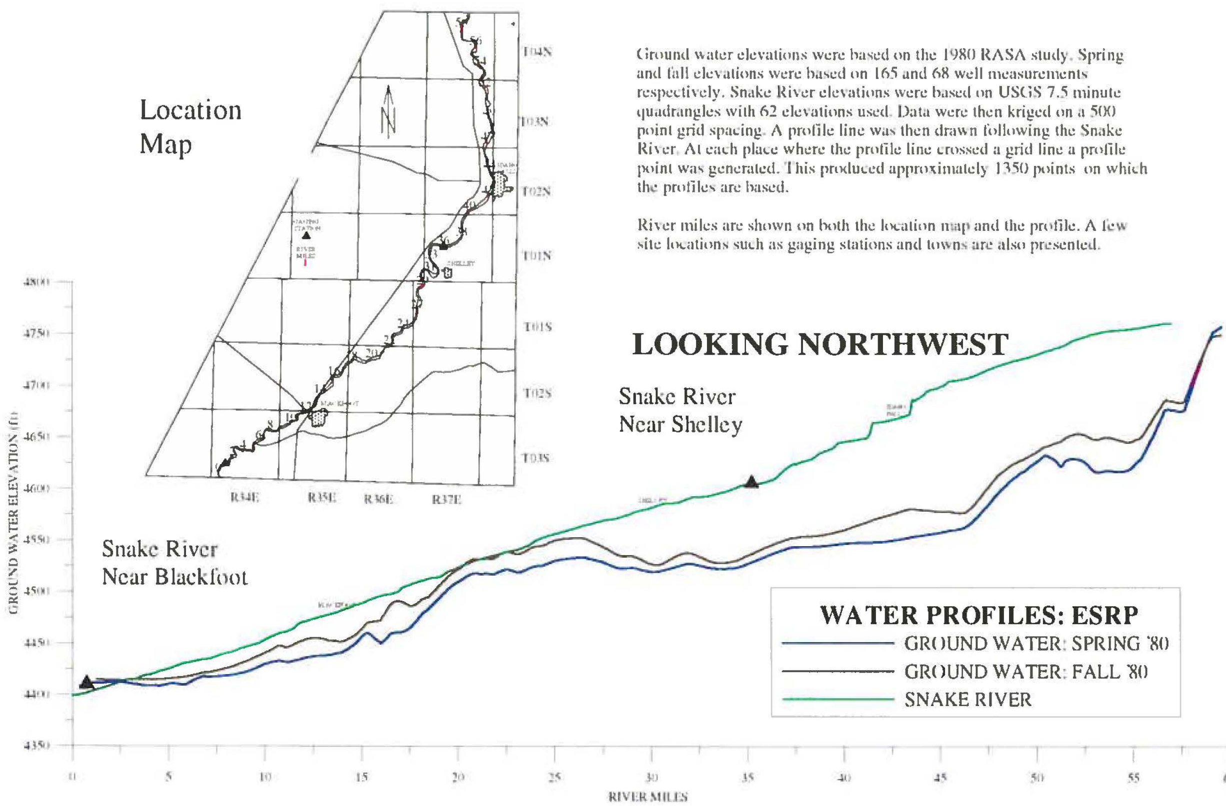


Figure 14. Annual Average Unidentified Gain Snake River - Heise to Milner

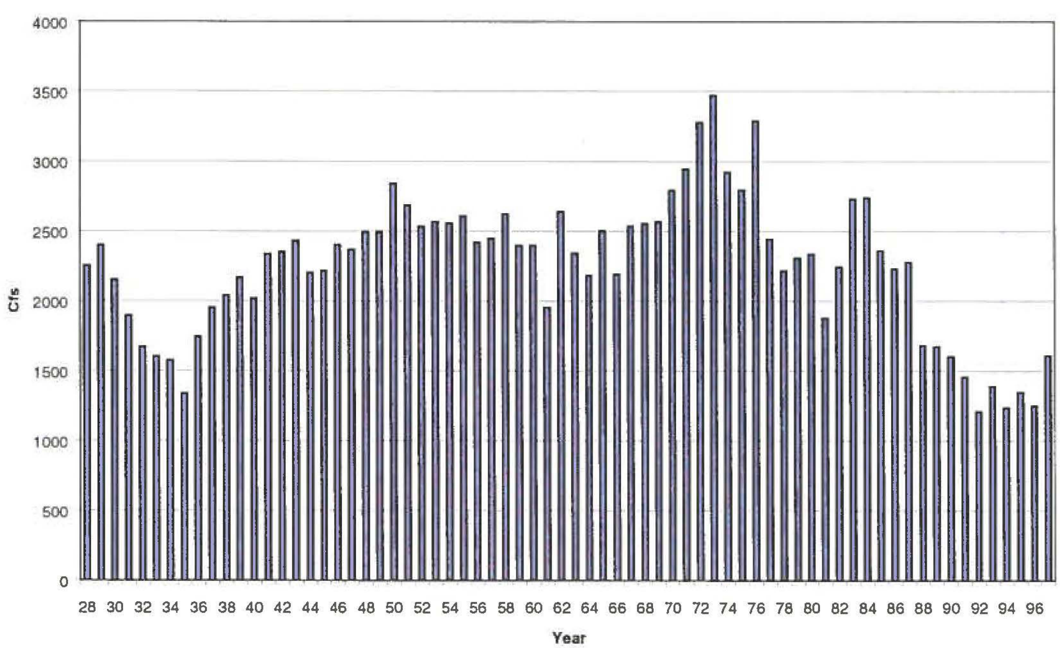
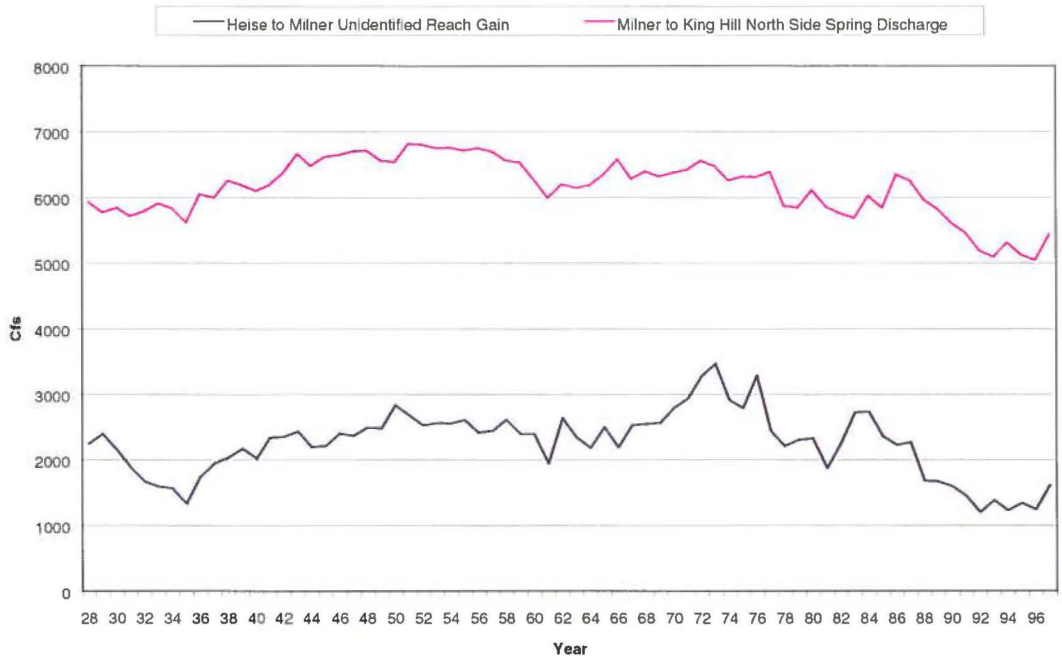


Figure 15. Comparison of Above and Below Milner Gains - Snake River



While it can be said that, in general, the gains above Milner have shown the same response as the gains below Milner, the response cannot be attributed to any single factor. The actual gains are greatly influenced by irrigation recharge and overall water supply conditions. The calculated gains include ungaged local runoff and any errors in estimates of surface returns from irrigation. However, general trends can be observed and partially explained using the calculated gains. Specifically, the effects of ground water irrigation depletions, which are in the range of 2000 cfs, are at least partially visible in the gain data both above and below Milner. Above Milner, the depletion effects are found by looking at reaches beyond the Blackfoot to Neeley reach. The depletion effects of ground water have also been partially offset by wetter than average water supply conditions coinciding with the advent of pumping and continuing in recent years.

<u>Conclusions</u>

1. The IDWR/U of I ESPA ground water model calibration cannot be significantly improved using currently available data.
2. Model results are insulated from calibration errors by computing the effects of changes in recharge in terms of changes from the base condition simulation.
3. Performing a transient simulation of previous years would enhance confidence in the ESPA ground water model.
4. The ESPA model produces results very similar to the USGS RASA model.
5. Historically observed stream flows, ground water levels and computed reach gains cannot be used to directly confirm the ESPA modeled results.
6. The Blackfoot to Neeley reach of the Snake river cannot be used in isolation to show ESPA river response above Milner.

7. The reach of the Snake River above American Falls Reservoir is head dependant extending at least 25 miles above the near Blackfoot gage.
8. The effects of ground water pumping over the ESPA have been in part compensated for by above average water supply conditions.
9. Reach gains above Milner exhibit the same general pattern as those gains below Milner.
10. ESPA modeled Snake River response coefficients provide the most accurate and reliable information available on the effects of changes in recharge over the ESPA.