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Eastern Snake Plain Aquifer Modeling Scenario:

Hydrologic Implications of Current Water-use Practices and Historical Climate Conditions

"Current Practices" Scenario

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INTRODUCTION

(Standard intro from other scenarios, plus:)

With continuing concern over spring discharges and Snake River gains, it is important to consider the hydrologic implications of current water-use patterns and practices: Are current levels of withdrawal sustainable in light of current recharge? Would a return to normal hydrologic conditions cause a rebound in discharges and gains?

With a constant aquifer stress, aquifer storage would eventually stabilize and cease to influence spring discharges and reach gains. The net discharges and gains would equilibrate to a level identical to the net of other discharge and recharge in the system. A water budget analysis could therefore answer all the questions presented. However, it would neither indicate the length of time expected to reach a hypothetical equilibrium nor the spatial distribution of the equilibrium aquifer discharges. This scenario, "Hydrologic Implications of Current Water-use Practices and Historical Climate Conditions," addresses these additional questions by applying the water budget to a calibrated aquifer model in a transient run extending many years into the future. This provides an indication of the equilibrium condition suggested by current practices, describes the spatial distribution of equilibrated discharges and gives an indication of how long it would take to reach this hypothetical equilibrium.

The three possible outcomes of the scenario represent three different possibilities for the current hydrologic state of the aquifer:

1. The simulation could indicate that the aquifer would return to higher levels of spring discharges and river gains.
2. The simulation could indicate further declines in spring discharges and river gains.
3. The simulation could indicate that the expected equilibrium condition includes spring discharges and reach gains similar to current levels.

The scenario necessarily projects results out into future years. However, the scenario *is not* and *cannot be considered* a prediction. Its fundamental assumptions - that *current* practices and *historical* hydrologic conditions are to be represented - are counter to actual expectations for the future. Human water-use patterns and practices will surely continue to change, and it is possible that hydrologic conditions will also change.

While the scenario is constructed to indicate implied equilibrium conditions, it is not expected that any of the represented equilibrium conditions actually will be reached, for two reasons: 1) Actual future discharges and gains will largely be driven by future events which are explicitly *not* included in the scenario. 2) The simulations use a constant aquifer stress, which cannot represent the winter-to-summer, year-to-year and cyclical hydrologic variability that has been observed in the past and is expected in the future.

This scenario, designed to assess the implications of the status quo, is potentially useful for informing decisions regarding current activities. However, it is neither an assessment of expected changes in practice or hydrologic condition, nor a forecast of short-term or long-term spring discharges and reach gains. Such assessments and forecasts could be useful and may appropriately be the subjects of future work, but they are not the subjects of this scenario.

The outcome of the scenario is actually the third possibility presented above: It suggests that the equilibrium condition associated with today's surface-water diversions, ground water use, crop mix, application methods and water-use efficiencies is a condition of spring discharges and river gains very similar to today's levels. Implications of the scenario include:

1. We have already experienced most of the drought recovery that may be expected.
2. Most of the effects of ground-water development have also propagated to the river.
3. Current water use and extraction are approximately in balance with recharge, at the current levels of spring discharges and river gains.
4. Historical variability in reach gains and spring discharges far overshadows the small differences between today's condition and the implied equilibrium condition. While the long-term equilibrium is similar to today's levels, future spring discharges and gains should be expected to be range significantly higher and lower than today's levels even if practices and the overall hydrologic regime remain constant.

METHODS

The methods for this scenario were guided by the Eastern Snake Hydrologic Modeling Committee (ESHMC) and discussed extensively within the committee. The basic approach was to construct data sets representative of today's water use patterns and average hydrologic conditions, and model these out into the future, in order to discover the implied equilibrium condition associated with today's practices. Steps included:

1. Extend the calibration-period data (which ended 30 April 2002) through April 2007, in order to start the scenario with a representation of today's conditions.
2. Test the extended data by using them in a model run and comparing model outputs to observed water levels, spring discharges and river gains.
3. Select candidate pools of data from which to construct the representative data sets, in order to capture current human water-use practices.
4. Select hydrologic indices to guide extraction of data from the candidate pools, in order to represent average hydrologic conditions.
5. Use the hydrologic indices to construct representative data sets.
6. Use the data sets in model runs to generate implied equilibrium conditions.
7. Explore the historical variability of reach gains and spring discharges, in order to provide some context for the differences between today's condition and the implied equilibrium conditions, and to illustrate the future variability that should be expected even if practices or average hydrologic conditions were to remain constant.
8. Assess the time required to reach the implied equilibrium condition, from today's condition.
9. Compare results of representative data sets, in order to understand the implications of the assumptions associated with different candidate pools and indices.

Extended Data Set

The ESHMC determined that it was important for the scenario to provide an indication of the period of time that would be required for the aquifer to meet the new equilibrium condition implied by the scenario water budget. To correctly model the transition from today's condition to the hypothetical equilibrium condition, the model simulation must include a reasonably accurate representation of today's aquifer heads. The ESHMC considered three options:

1. Interpolate recently-measured heads across the study area. This option was rejected because scarcity of data would leave large areas represented only by interpolated values, which were judged to be unreliable for the required purposes.
2. Use recently-measured heads to adjust the modeled ending heads from the last calibration period (30 April 2002). This option was also rejected.
3. Apply an extended recharge and discharge data set in a short model run to bridge the period 1 May 2002 - 30 April 2007, and use ending

heads from that model run as starting heads for the scenario simulation. The ESHMC selected this option because the model produces a head estimate for every model cell in the study area, based on the input water-budget data.

The extended recharge and discharge data set used actual precipitation and diversion data where possible, and used values from the calibration period as proxies for other components of the water budget. Based on natural flow at Heise (citation), the Palmer Drought Index (citation) and SNOTEL data (citation), model year 2000 was selected as a proxy for model years 2002 through 2005, and model year 1999 was selected as a proxy for model year 2006. Table 1 summarizes the components of the extended data set and the source of data or proxy used for each component:

Table 1
Inputs to model run "CombinedRun_1,"
used to generate starting heads for Current Water Use Practices Scenario

Component	**Abbreviation for recharge tools**	**Representation in Extended Data Set**
Sprinkler percentage		Most recent calibration data (model-year 2001)
Irrigated Lands		Year-2000 LANDSAT data[1]
Starting Heads		Modeled heads, spring 2002, from calibration data sets[2].
ET on irrigated lands, 2002-2005	EIR	Calibration data 2000
ET on irrigated lands, 2006	EIR	Calibration data 1999
Precipitation on irrigated lands	PRI	PRISM through February 2007. PRISM data corresponding to model-year 1999 for March and April 2007.
Surface-water diversions, Snake River and Wood Rivers, 2002-2005	SWV	IDWR diversion data
Surface-water diversions, Snake River and Wood Rivers, 2006	SWV	Calibration data 1999
Surface-water	SWV	Calibration data 2000

[1] Calibration used a 1992 landcover data set based on 1987 aerial photos and subsequent field inspection.
[2] Calibration runs used 365-day years, ignoring leap year. Calibration data were re-run with 365.25-day years to generate equivalent spring-2002 heads.

Component	Abbreviation for recharge tools	Representation in Extended Data Set
diversions, other sources, 2002-2005		
Surface-water diversions, other sources, 2006	SWV	Calibration data 1999
Return flows		Wood Rivers used measured returns from IDWR data files. Other entities used measured fractions from the year of measurement if available, and used the most recent measured data otherwise. In most cases measured data extended through 2003 or 2004.
Offsite Pumping, 2002-2005	OFF	Calibration data 2000
Offsite Pumping, 2006	OFF	Calibration data 1999
Fixed-point pumping[3], 2002-2005	FPT	Calibration data 2000
Fixed-point pumping, 2006	FPT	Calibration data 1999
Perched-river (non-Snake) seepage, 2002-2005	PCH	Calibration data 2000
Perched-river (non-Snake) seepage, 2006	PCH	Calibration data 1999
Tributary underflow, 2002-2005	TRB	Calibration data 2000
Tributary underflow, 2006	TRB	Calibration data 1999
Canal leakage, 2002-2005	CNL	Calculated from diversions, using 2001 leakage fractions
Canal leakage, 2006	CNL	Calculated from 1999 diversions using 2001 leakage fractions

Test Extended Data

The extended data were appended to model-calibration data, forming a 27-year data set. These data were then applied to a model run using Eastern Snake Plain Aquifer Model 1.1 (ESPAM 1.1) aquifer parameters. Aquifer-level hydrographs were generated for selected locations, along with spring discharge and Snake River gain and loss hydrographs. These were visually compared with target data for a qualitative assessment of three factors:

[3] Fixed-point pumping data include adjustments for deficit irrigation in the Richfield tract.

1. Are head levels and discharge rates indicated by the extended data compatible with the results from calibration data?
2. Are the patterns (trend, seasonality, amplitude) from the extended data compatible with the calibration data?
3. Are the post-2001 trends from the extended data compatible with the trends in the observed targets?

Select Candidate Pools of Data

After considerable discussion, the ESHMC selected two candidate pools from which to extract the representations of the current condition:

1. Ten-year pool: Calibration data for model years 1992 through 2001.
2. Fifteen-year pool: Calibration data for model years 1992 through 2001 and extended data for model years 2002 through 2006.

Years prior to 1992 were not used because it was felt that they would not be representative of today's application methods, allocation patterns, crop mix and practices.

The ESHMC could not prefer either pool over the other, because each has a unique advantage. The ten-year pool has the advantage of including no synthesized data, which greatly reduces concerns that a bias in estimates would propagate into the final result. The fifteen-year pool has the advantage of offering more options and a broader range of stress from which to select in constructing a representative data set. Because both pools had desirable characteristics, both were used in the scenario data sets.

Select Hydrologic Indices to Guide Extraction of Data

Both candidate pools are believed to represent current allocation patterns and water-use practices, but implicit within the candidate pools are also the hydrologic conditions that occurred during those years. In order to extract from the candidate pools data that are representative of the long-term average hydrologic condition, some kind of selection or weighting criterion is required. The method chosen was to use a hydrologic index to guide selection. As with the candidate pools, the ESHMC was not able to identify one clearly superior index, so three different indices were used:

1. Heise index; natural flow at Heise, with consideration of antecedent condition. Data were obtained from US Bureau of Reclamation (citation). This index is identified in modeling data files with the prefix "H."
2. Dual index; natural flow at Heise with antecedent condition, combined with summer-time temperatures at Aberdeen (citation). The two indices are equally weighted in the selection process. This index is identified with the prefix "D."
3. Palmer Drought index (citation) identified with the prefix "P."

An index based on carryover storage was rejected because it was believed that it would not be time constant. That is, the index for a later year would be different than the index for an earlier year of identical hydrologic characteristic, due to changes in total storage capacity, development of the rental pool, use of storage for flow augmentation and use of storage for hydropower generation. These are use characteristics that are believed to be implicitly included within the candidate pools, and should not be confounded in the process of selection[4].

An index based on snow-pack observations was rejected because of surprisingly low correlation with the aquifer water budget, for years when both data sets were available.

Use Indices to Select Data and Construct Data Sets

The goal of using the indices was to select from the candidate pools data which were representative of the "average" hydrologic condition. This was done by assigning an index value to each year in the candidate pool, based on the full period of record (back to the early 1900s for natural flow and temperatures, to the late 1800s for the drought index). Each year in the candidate pool was assigned a weight, so that (weight x index) for all the years summed to approximately 1.0. The resultant "representative data set" was the sum of (weight x net recharge) for all the years in the candidate pool.

With ten or fifteen candidate years in each pool, there would be an infinite number of combinations that could satisfy the criterion that the weighted index be approximately 1.0. For instance, Table 2 illustrates two different weighting schemes for hypothetical years "A," "B" and "C:"

Table 2
Hypothetical Application of Weights to Candidate Years

Candidate Year	**Index**	**Scheme 1 Weight**	**Scheme 1 Weight x Index**	**Scheme 2 Weight**	**Scheme 2 Weight x Index**
A (dry)	0.5	0.5	0.25	0	0
B (average)	1.0	0	0	1.0	1.0
C (wet)	1.5	0.5	0.75	0	0
Sum		1.0	1.0	1.0	1.0

Intuitively, we reject both of these schemes. Scheme 1 ignores the mid-range condition, which occurs frequently and should be included in a representation of expected conditions. Scheme 2 ignores the extreme events, which also should have some representation in the final data set. Table 3 shows an allocation that

[4] There may not have been full consensus on this point within the ESHMC.

gives a weighted index of 1.0 and also matches our intuitive expectations of relative frequencies of wet, dry, and average years:

Table 3
Alternate Hypothetical Application of Weights to Candidate Years

Candidate Year	**Index**	**Scheme 3 Weight**	**Scheme 3 Weight x Index**
A	0.5	0.25	0.125
B	1.0	0.50	0.500
C	1.5	0.25	0.375
Sum		1.0	1.0

In order to objectively apply weights to individual candidate years, a frequency histogram of index values was constructed from the period of record for each index, and candidate years were assigned to histogram bins according to their individual index values. Bins were combined into categories based on the available years in the candidate pools; the ten-year pool had fewer categories than the fifteen-year pool. The relative frequencies of the categories that the years represented were used to assign target frequencies for consideration in applying weights.

The drought index and temperature index considered only the individual index value of candidate years, while the natural flow index also considered the antecedent condition. For instance, year 1998 was a moderately wet year with a wet antecedent condition. During the period of record, years in that category occurred with a frequency of 0.105; hence, the desired frequency for candidate year 1998 was 0.105. Candidate years 1993 and 2000 both fell in the same category (dry, with average antecedent condition), whose historical frequency was 0.252. Each of those candidate years was assigned a desired frequency of half that amount, or 0.126. Candidate year 1996 was a very wet year, with a wet antecedent condition. This was a rare occurrence in the record; consequently, candidate year 1996 has a very low desired frequency.

In constructing the weighting scheme, three criteria were applied: a) The weights will sum to 1.0; b) The weighted average index of the candidate years will be very near 1.0; c) The weight for each individual candidate year will be near its desired frequency (as described above). The optimization of these criteria was performed using the Solver tool in the Microsoft Excel spreadsheet. Figure 1 illustrates a typical result. In all six cases, all criteria were reasonably satisfied. All solver solutions are included in the appendix.

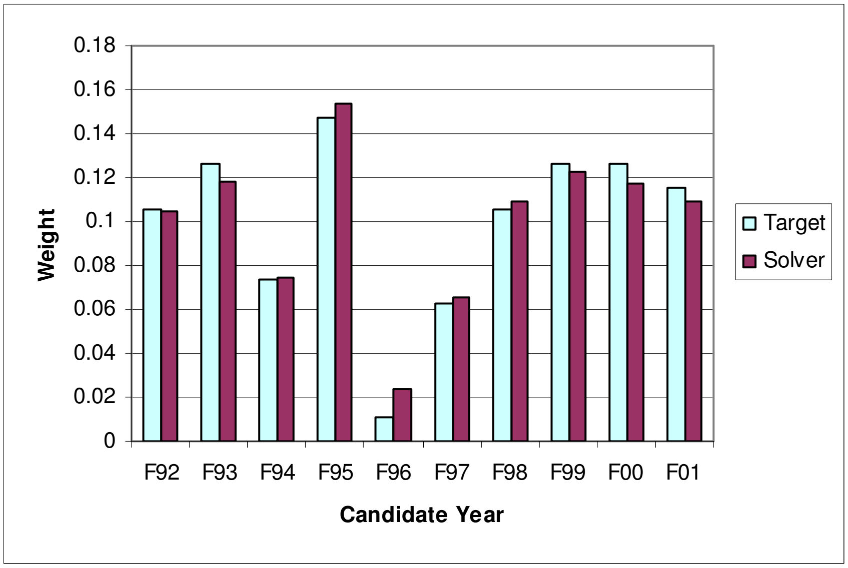

Figure 1. Comparison of target frequencies (from frequency histogram) and solver-assigned weights for a representative data set. The weighted average index is 0.996 and the sum of weights is 1.0001, both very near the target of 1.0

Once the weights were obtained for each year in the candidate pools, the representative data sets were constructed by multiplying the MODFLOW well file[5] for each candidate year by the solver weights, and summing across candidate years.

The combination of two candidate pools and three hydrologic indices produced six representative data sets. All are considered valid best estimates of the representation of current practices and average hydrologic conditions, and none can be preferred above the others. All six were used in the scenario, as described below.

Use Constructed Data Sets in Model Runs

A stress period is a period of time during which the MODFLOW well file, representing net recharge and discharge to the aquifer, is held constant. Model calibration and some previous scenarios used six-month stress periods in order to represent the seasonality of aquifer stress, spring discharges and river gains. This is appropriate when a representation of seasonal variability is important to the modeling purpose. In the Current Practices scenario, however, the primary purpose was to establish implied equilibrium average discharges, and a secondary purpose was to describe the expected change from today's condition

[5] MODFLOW is the modeling software that ESPAM 1.1 is built upon. The MODFLOW well file is an input file to a modeling run, used in this case to contain all water-budget recharge and discharge data except spring discharges and Snake River gains and losses. It contains one entry for each model cell, for each stress period of a modeling simulation.

to this hypothetical equilibrium. If the scenario were to use seasonally-variable stress periods, one could produce the situation illustrated in Figure 2, where an apparent "improvement" from today's situation to the final equilibrium condition is simply the difference between seasonal and average representations, rather than a difference between current and equilibrium conditions.

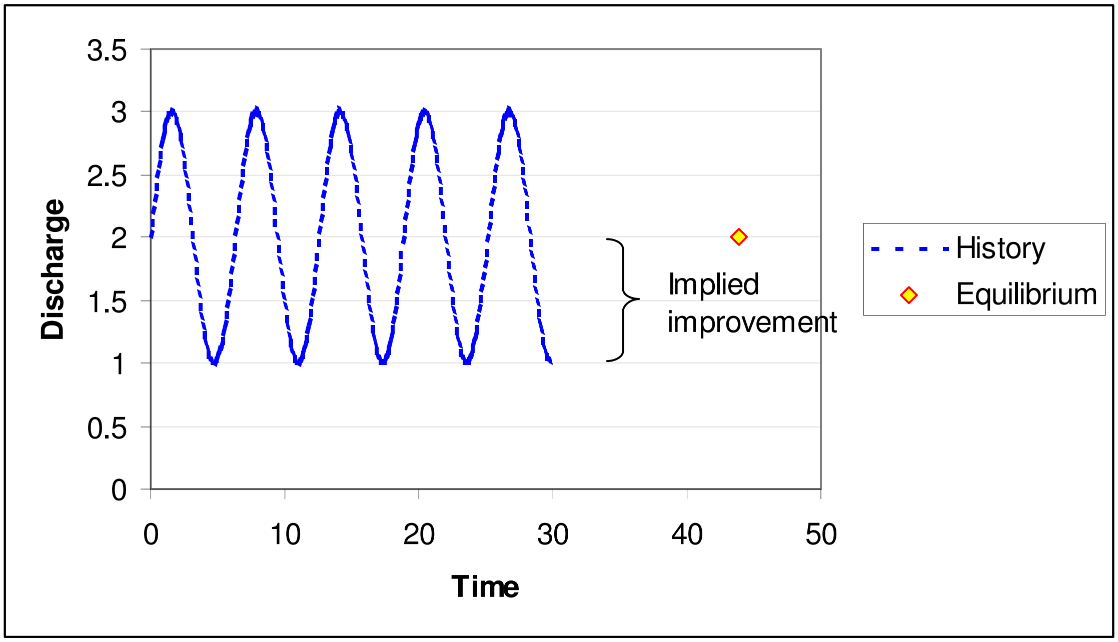

Figure 2. Hypothetical simulation showing how seasonal effects could be mistaken for a difference between the current condition and an eventual equilibrium average condition.

In order to avoid this potential of a false indication of trend, the scenarios were run with average annual stress. To achieve the equivalent annual average starting heads that would be representative of spring 2007, the entire 27-year series was recombined into a data set with annual stress periods. The six representative data sets described above were also constructed as annual-stress data sets. From these, six 327-year data sets were constructed. Each included 22 years of calibration data, five years of extended data, and 300 years of representative average stress. Each of these data sets were processed with ESPAM 1.1, using the calibration starting heads for the simulation start date of 1 May 1980. Each year was 365.25 days long, compatible with the assumptions used in construction of the original recharge data. Discharge and reach-gain data were extracted at the end of each year. Head data were extracted at the end of each of the first 77 years, at the end of the 80th year, every five years thereafter until year 100, every ten years through year 320, and the at the end of year 327.

Explore Historical Variability of Spring Discharges and Reach Gains

It is important in considering the implications of current practices to understand not only the implied average condition, but to understand how much variability could be expected about the implied average. In a transient MODFLOW aquifer model, a time-variable input data set can produce a time-variable output series. After considerable discussion with the ESHMC, IWRRI rejected a time-variable approach because neither candidate pool contains a full complement of years of various hydrologic character. In such a case, IWRRI believes the output could not fully represent the potential variability that would be expected[6].

Instead, the process described above was used to produce six constant-stress transient model runs which generated results that could be considered traces of mean spring discharges and reach gains. If current water-use practices were to continue in an environment of water-supply variability and cyclical behavior, one would never expect actual spring discharges and gains to match the simulation results. However, one would expect them to range within an envelope surrounding the simulated traces (assuming no underlying long-term trend in hydrologic regime). The representation of potential future variability was extracted from the historical data (for Snake River reach gains) or from the 27-year data set of calibration and extended data (for spring discharges). Variability was extracted by generating trend lines using ordinary least squares regression, and subtracting the trend from the data set. When the character of the historical trace appeared to change, separate trend regressions were constructed for each period of the record[7]. Separation into periods was based on visual inspection of the data. Figure 3 illustrates one such division, where gains are divided into three periods for trend analysis.

The historical data include some extreme values, so the representation of variability for Snake River reach gains was based on the 20th and 80th percentiles of de-trended observed data. Because the spring variability was based on modeling results, which do not show individual short-term events, the full range of observed variability in model results was used to represent variability in spring reaches.

[6] The ESHMC may not have unanimously agreed to this opinion.
[7] When trend regressions were not statistically significant, the mean value for the period was used to represent trend.

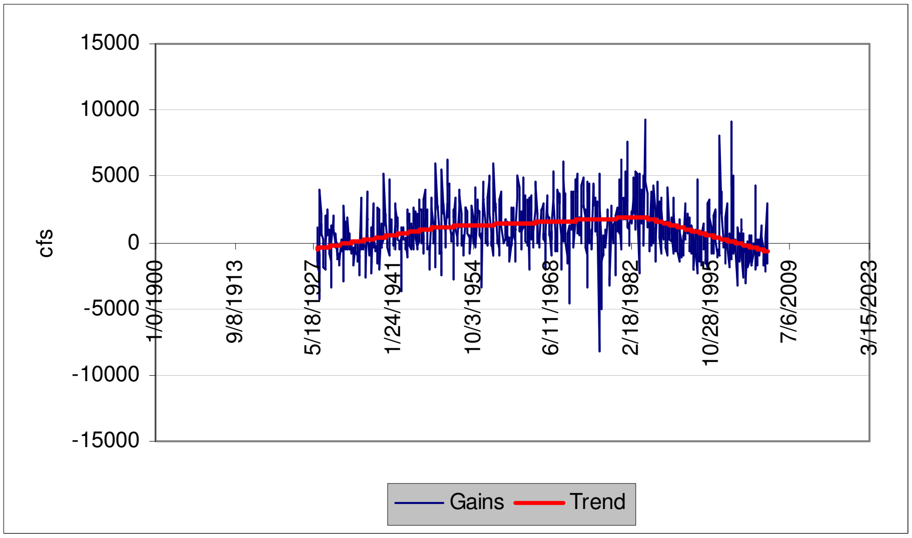

Figure 3. Historical reach gains and trend analysis for St. Anthony to Rexburg reach.[8]

Assess Time Required to Reach Hypothetical Equilibrium

This assessment was approached by determining how soon (in years) the simulated discharge or reach gain was within 10% of the final value, for each reach and simulation data set.

Comparison of Results of Representative Data Sets

The flow results of the six data sets were compared by tabulating the final simulated equilibrium conditions and the magnitude of differences, and by graphing the time-series traces of the change in the mean simulated discharge or gain. Head results were compared by visual inspection of 300-year water-level change maps (year 327 minus year 27).

RESULTS

Test of Extended Data Set

The appendix contains illustrations of all the comparisons made. Figure 4 and Figure 5 show sample results. Two factors are important to consider in looking at these figures:

1. Spring-discharge model results are for entire reaches, while targets represent discharge of individual springs within reaches. Therefore, absolute magnitudes cannot be directly compared.

[8] The model results are for Ashton to Rexburg, but the available target data were for St. Anthony to Rexburg.

2. Modeled reach gains represent only the exchange between the aquifer and the river. Target reach gains also include return flows. Again, absolute magnitudes cannot be directly compared.

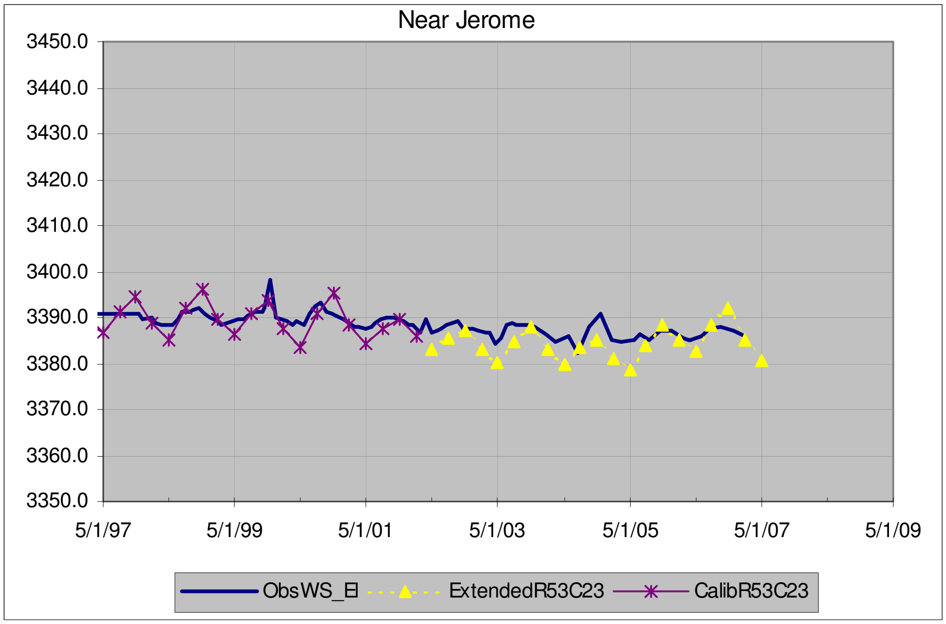

Figure 4. Sample aquifer head comparison.

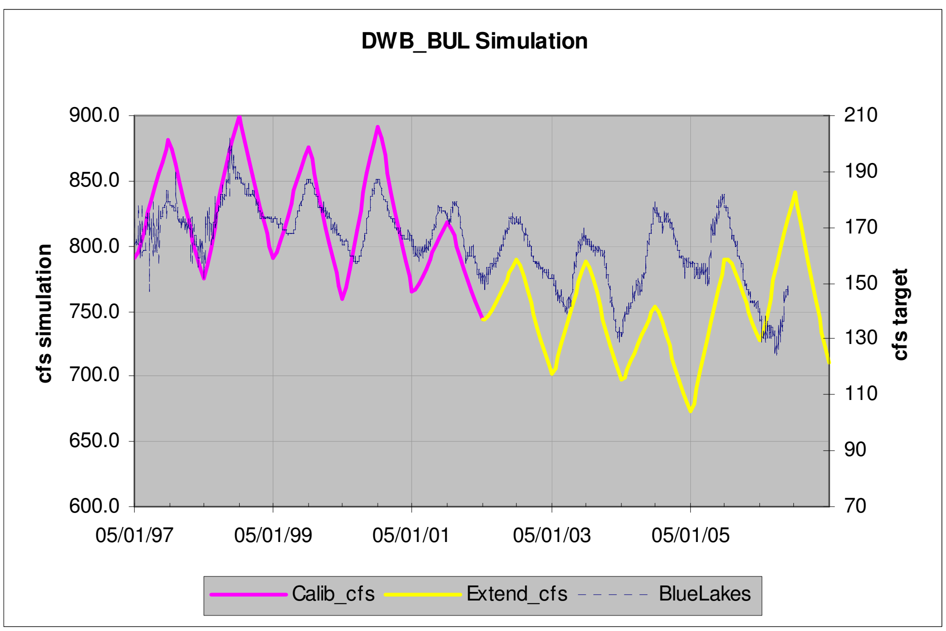

Figure 5. Sample spring-discharge comparison. Note that simulations use the left vertical axis and the target uses the right axis.

Based on the criteria listed earlier, the extended data set cannot be rejected; its general head levels and discharges are compatible with the calibration data; its trend and variability characteristics are compatible with calibration data; and, its post-2002 trend is not grossly inconsistent with the trend observed in target time series.

Equilibrium Hydrologic Conditions Implied by Current Practices

Aquifer water levels are buffered by the river or spring elevations near the river and springs, so simulated equilibrium levels in those areas are not too different from current levels. However, in areas distant from the river, heads can differ by as much as one hundred feet or more. Further, the six simulations differ substantially from one another. Figures 6 and 7 illustrate two of the difference maps. All six are illustrated in the appendix.

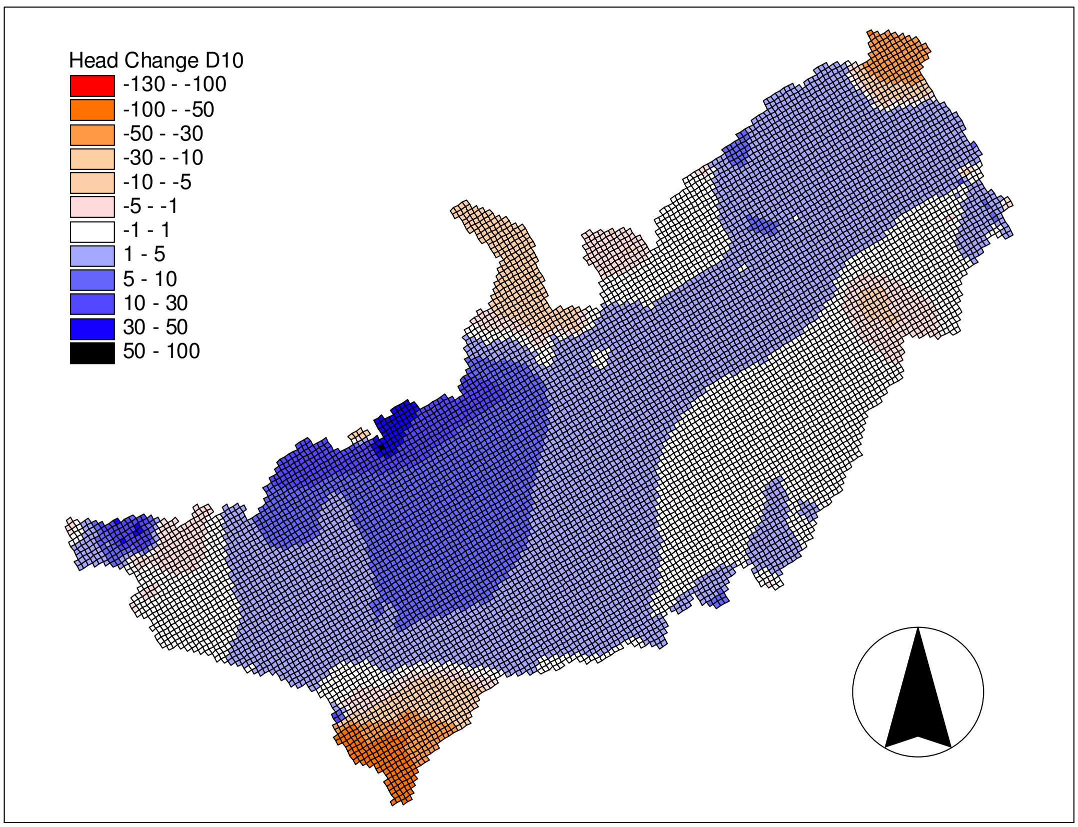

Figure 6. Head change map from ten-year candidate pool, dual-index selection method.

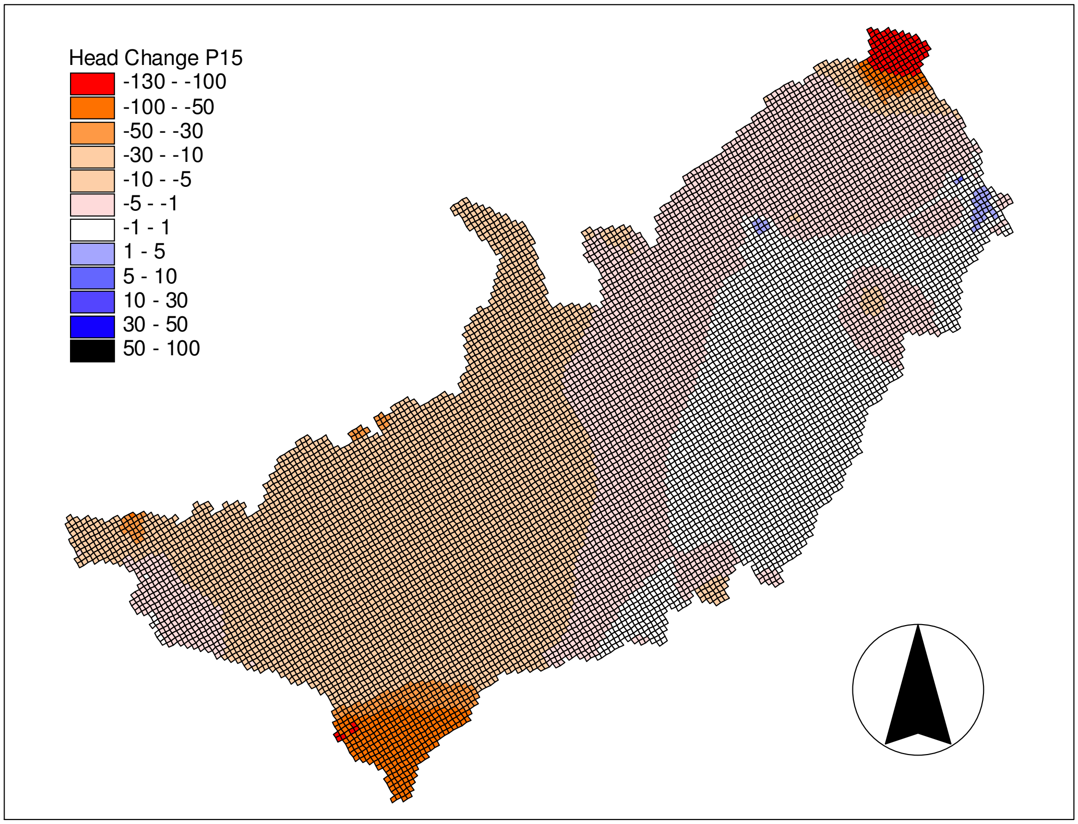

Figure 7. Head-change map from fifteen-year candidate pool, drought-index selection method.

Spring discharges and river gains are very similar to current levels. Table 4 summarizes the reach gain results and Table 5 summarizes the spring discharge results. Full results are displayed in the appendix.

Table 4
Simulated 2007 and Equilibrium Reach Gains,
Six Representative Simulations
(Simulated season-average flow in cfs. Positive numbers are reach gains and negative numbers are losses to the aquifer.)

Reach	**2007**	**Median Equilibrium**	**Maximum Equilibrium**	**Minimum Equilibrium**
Ashton-Rexburg	60	137	180	-8
Heise-Shelley	-744	-742	-719	-776
Shelley-Near Blackfoot	-878	-853	-837	-892
Near	2373	2449	2508	2287

Reach	2007	Median Equilibrium	Maximum Equilibrium	Minimum Equilibrium
Blackfoot - Neeley				
Neeley-Minidoka	53	51	68	29

Table 5
Simulated 2007 and Equilibrium Spring Discharges,
Six Representative Simulations
(Simulated average discharge in cfs)

Reach	2007	Median Equilibrium	Maximum Equilibrium	Minimum Equilibrium
Devils Washbowl - Buhl	679	685	701	610
Buhl-Thousand Springs	1510	1509	1516	1473
Thousand Springs	1955	1952	1957	1922
Thousand Springs-Malad	62	61	61	60
Malad	1212	1204	1206	1183
Malad-Bancroft	127	127	128	121

The median results suggest improvement in all the Snake River reaches except Neeley to Minidoka. Only in the Ashton-Rexburg reach is the median change meaningful on a percentage basis, and probably in none of the reaches is the change of practical significance, in terms of volumes of water. Overall, results are ambiguous for the Snake River reaches; for each reach, the best of the six representations suggests an improvement and the worst suggests a decline. Median spring-discharge results suggest slight declines in four reaches, a slight improvement in one, and no change in one reach. Again, the changes are small in percentage and in absolute magnitude. Two reaches show slight declines with all six representations, while the other reaches include representations of improvement and representations of decline. All differences are small relative to measurement precision and data uncertainty.

Explore Historical Variability - Snake River Gains

As described in the "methods" section, the data were de-trended and some simple moving averages were applied to consider cyclical behavior. Figures 8 through 12 illustrate the typical variability of river gains. Other reaches are illustrated in the appendix. Figure 8 shows the de-trended reach gains with an 83-month centered moving average. The moving average still does not filter out some longer-term cyclical behavior. Figure 9 is the same de-trended time series with a 13-month centered moving average, which suggests the existence of some higher-frequency cyclical behavior, along with the longer-frequency behavior shown in Figure 8. Figure 10 shows the de-trended data with the 13-month moving average also removed. Figure 11 and Figure 12 show the traces of the six representative methods with bars representing the 20th and 80th percentiles of the de-trended variability added to the highest and lowest of the six methods. These figures are typical of the river data; the largest variability is in seasonal behavior, but even the cyclical variability is of greater magnitude than the differences between representative data sets and the differences between equilibrium and current conditions.

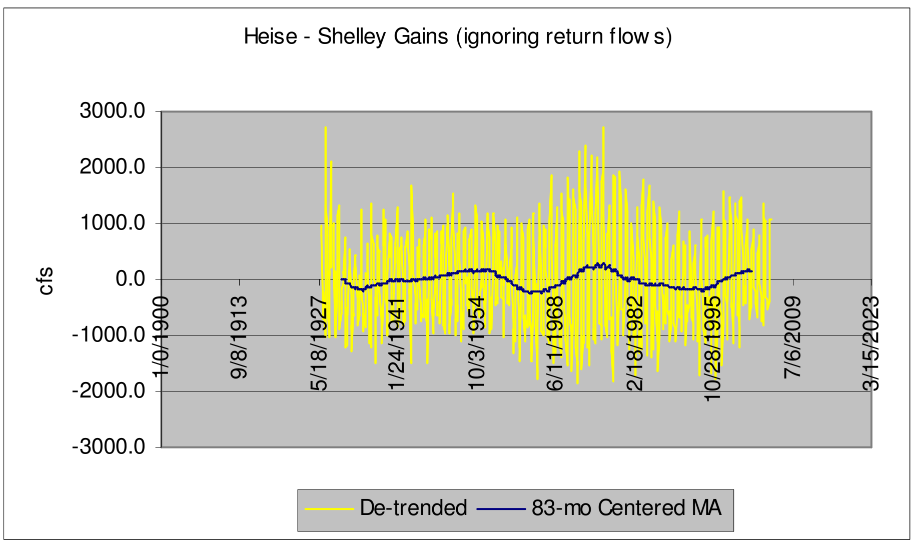

Figure 8. De-trended Heise-Shelley reach gains with 83-month moving average.

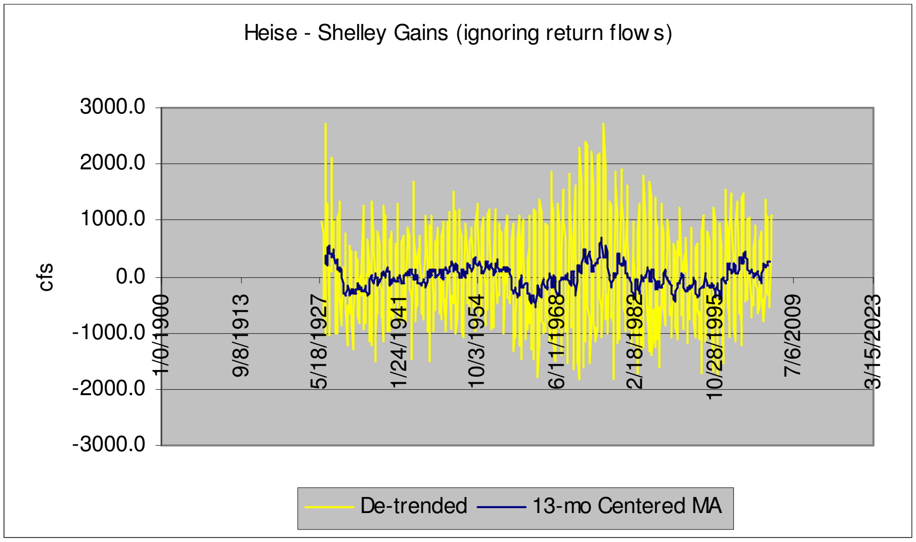

Figure 9. De-trended Heise-Shelley reach gains with 13-month centered moving average.

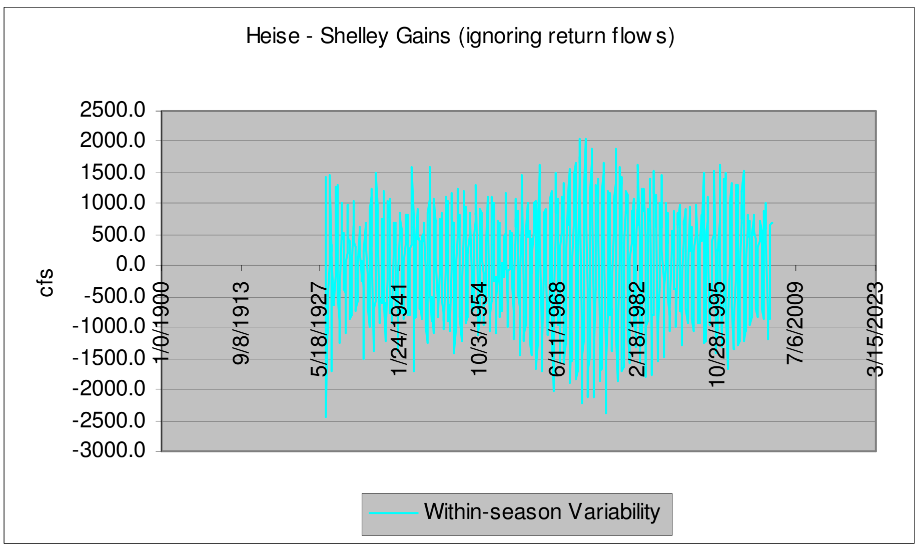

Figure 10. De-trended Heise-Shelley reach gains with 13-month centered moving average removed from data.

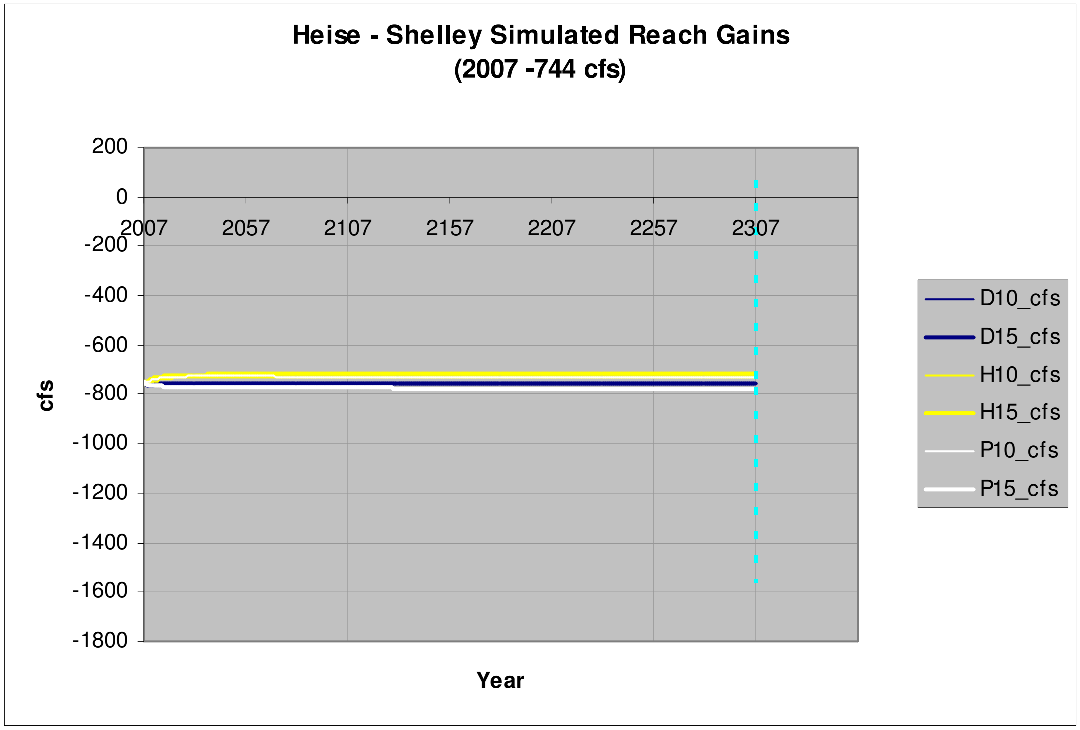

Figure 11. 300-year trace of six simulations for the Heise-Shelley reach, with the de-trended 20th and 80th percentiles shown as bars on the final year.

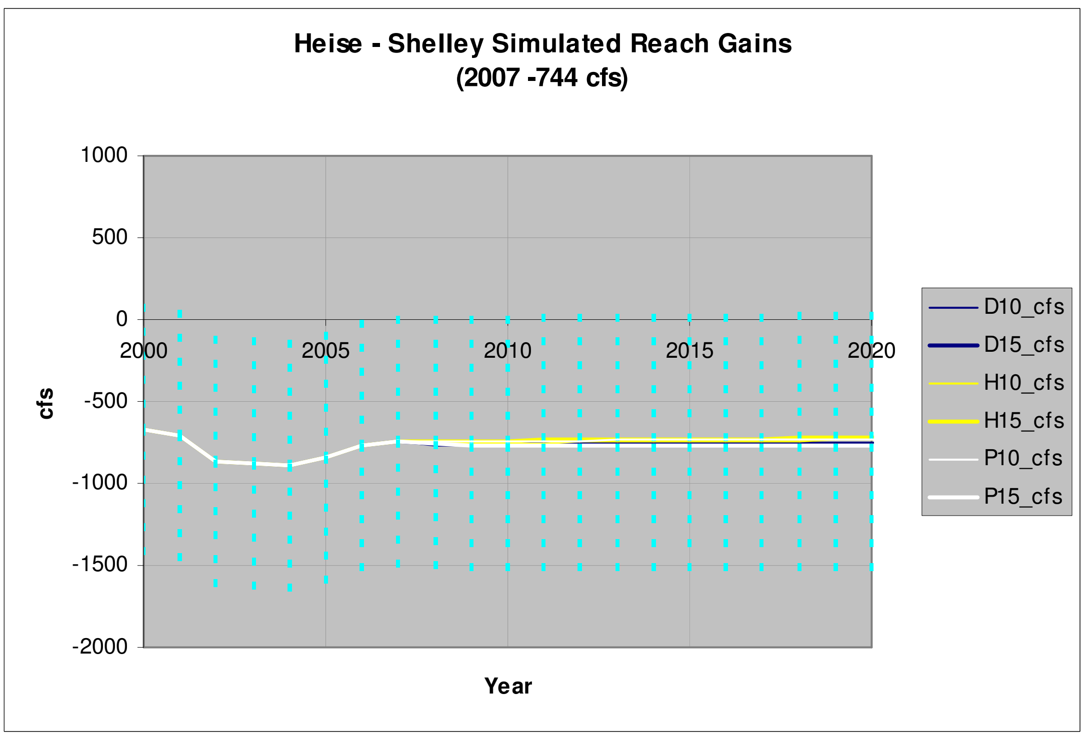

Figure 12. Close-up of the data shown in Figure 11 with 20th and 80th percentile bars shown on every simulation year.

This reach and others also appear to show periodic changes in variability. In contemplating the implications of the results of this scenario, the reader should consider the possibility that future changes may include changes in hydrologic variability.

Explore Historical Variability - Spring Discharges

As described in the "methods" section, spring discharge variability was assessed based on simulation results, due to lack of targets for some reaches and the fact that none of the targets represent the entire reach. Figure 13 shows a typical spring reach with its trend line.[9] The vertical axis is exaggerated to show the cyclical behavior; the inset shows the true relationship, with the vertical axis starting at zero. Figure 14 shows the de-trended variability, and Figure 15 applies this variability as bars on the traces of the six representative simulations. Other spring reaches are illustrated in the appendix. These figures are typical of the spring reaches; without formal time-series analysis, it appears that the cyclical behavior and differences between data sets are larger relative to the seasonal variability than for the river reaches. However, cyclical behavior is still fairly large relative to changes from current to equilibrium conditions. Table 4 indicates that the median equilibrium condition is within a few cfs of the current condition, but Figure 14 suggests a cyclical range of tens of cfs and a seasonal variability of perhaps 100 cfs.

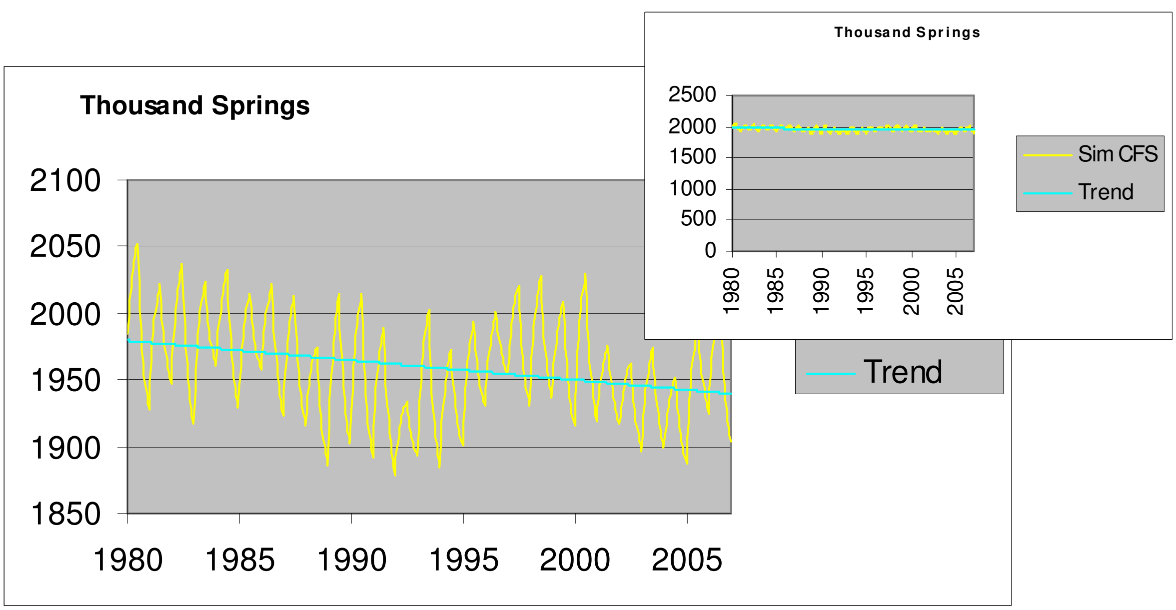

Figure 13. Twenty-seven year simulated discharge of Thousand Springs reach, with trend line.

[9] The trend in one reach was not statistically significant; for this reach, the mean value was used as the trend.

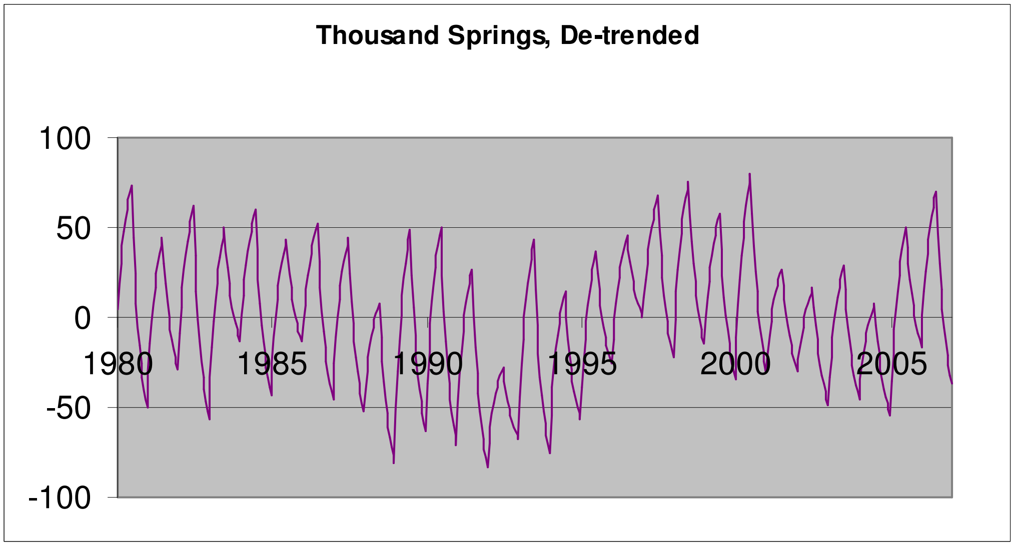

Figure 14. Thousand-springs reach variability, de-trended.

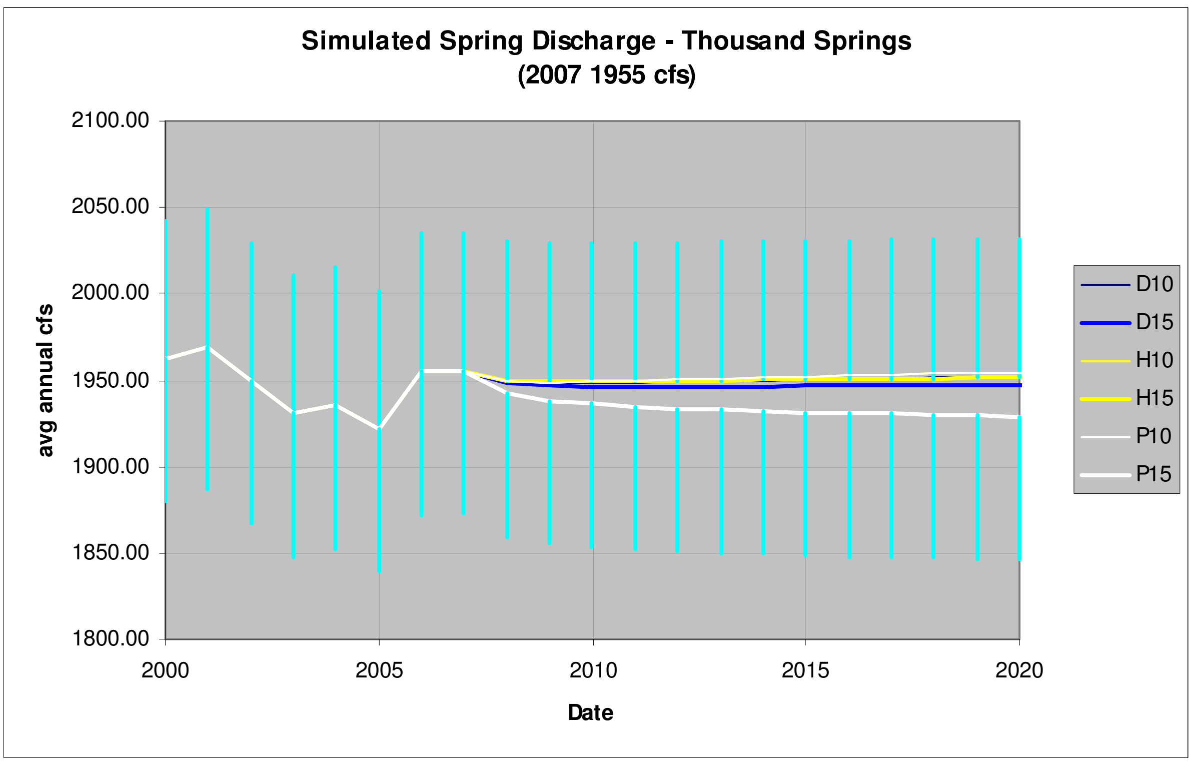

Figure 15. Simulated spring discharge from six methods, with bars representing the full range of de-trended variability.

Time to Reach Hypothetical Equilibrium

Most simulations showed such small changes that the simulated values were within ten percent of the equilibrium value by the spring of 2007 or 2008. The two exceptions are the Ashton to Rexburg reach, where the median time was 10 years with a maximum of 146, and the Neeley to Minidoka reach, where the median time was 0.5 years with a maximum of 53.

Comparison of Representative Data Sets

Table 4, Table 5 and Figures 11, 12 and 15 show that discharge and gains results are very similar across the six representative data sets, except for the Ashton to Rexburg and Neeley to Minidoka reaches. Even in those reaches the differences are small on a practical basis, relative to total flow in the river and relative to the precision of flow measurement and other data. It appears that little uncertainty is introduced into flow results by the differences between the six best-estimate data sets.

In contrast, Figure 6 and Figure 7 show that the different data sets produce markedly different equilibrium aquifer heads in locations distant from the springs and river. The differences are primarily in spatial distribution of water stored in the aquifer; average heads across the aquifer are similar for all six simulations. These spatial differences between methods cast doubt on the reliability of these distant-from-the-river head estimates. It appears that significant water-level uncertainty is introduced by differences between the best-estimate data sets.

CONCLUSIONS

The six representative data sets all suggest that equilibrium spring discharges and reach gains implied by today's practices and historical hydrologic conditions are not too different from today's discharges and gains. Small differences between the flow predictions of the six data sets suggest that data-estimation methods do not introduce significant uncertainty into flow results. However, aquifer-head results distant from the river contain considerable uncertainty associated with the different best-estimate data sets.

Hydrologic implications of the simulations and comparisons include:

1. No suggestion of significant future recovery of gains and spring discharges, unless a future event were to cause such a recovery.
2. No suggestion of a looming accumulated cone of depression migrating toward the springs and river to be expressed in the future.
3. Typical variability in gains and discharges is far greater than the differences between the six best-estimate data sets and the differences between any of them and current conditions.

The Current Practices scenario was designed around two questions: Are current levels of withdrawal sustainable in light of current recharge? Would a return to normal hydrologic conditions cause a rebound in discharges and gains?

The first question is partly a hydrologic question and partly a policy question. Hydrologically, the simulations suggest that current levels of extraction are compatible with current levels of spring discharge and reach gains; barring changes in climate or practice, we could expect continued variation around a mean discharge that is similar to today's conditions. Whether this is considered "sustainable" is a policy question.

There are two different answers to the second question: We should expect *neither* rebound nor decline associated with the current water use practices, but we should expect *either* rebound or decline associated with normal hydrologic variability. These two realities may provide useful guidance for policy decisions regarding current water allocation and water use practices. The second reality is sobering, but even more sobering and important is a third reality not addressed by this scenario: Human water use practices *will* certainly change over time, and climate *may likely* change as well.