To: File for controlled ground water area petition 41H-115474

From: Russell L. Levens, Hydrogeologist
DNRC Water Management Bureau

Date: February 19, 2008

Subject: Review of technical information for Sypes Canyon Controlled Ground Water Area

Introduction

The following are comments on selected written documents presented at the hearing on the Sypes Canyon Controlled Ground Water Area (CGWA) held on February 12, 2008. The documents included in this review contain comments on the report "Ground Water Conditions at the Sypes Canyon Temporary Controlled Ground Water Area" (DNRC report) and recommendations on the decision regarding the CGWA, but do not include any additional evidence or independent analysis.

Comments on Review by Michael Jones

As a background for my comments on the review by Michael Jones, in October 2005 I described the modeling approach followed in the DNRC report to a working group including Kathy Gallagher of the petitioner group, Alan English of the Gallatin Local Water Quality District, Scott Compton of the Bozeman DNRC regional office, and Dr. John Bredehoeft appearing as a consultant for the petitioners. Dr. Bredehoeft reviewed working versions of the models, advised on the modeling approach, and commented on drafts of the DNRC report. Kathy Gallagher and Alan English reviewed and commented on a preliminary draft of the DNRC report during August and September 2007.

The following are my general comments on Mr. Jones' review.

- A calibrated transient model could yield a better representation of the hydrogeologic system near the mountain front. However, I do not believe the number of wells with long-term water-level records or the frequencies of measurements for those wells are adequate to calibrate a transient model as proposed by Mr. Jones. Further, the effects of seasonal recharge on ground-water levels are dampened with distance from the mountain front and the value of a calibrated transient model diminishes considerably.
- Including the bedrock aquifer in the model might be valuable for the purpose of evaluating the effects of pumping from bedrock wells. However, data on the

hydraulic properties of bedrock and geometry of faulting are not available, and there are relatively few wells completed in bedrock with data to use for calibration of a transient model (or steady-state model for that matter). Therefore, there is insufficient data to model the bedrock aquifer and the relatively minor withdrawals from bedrock have a small effect on the alluvial aquifer system that was the focus of modeling. Again, a decision was made in consultation with the petitioners and their consultant Dr. John Bredehoeft to simplify the model representation of the bedrock and alluvial fan in the vicinity of the mountain front and focus on the effects of development in the large undeveloped western portion of the CGWA.

- Aquifer storage is not overestimated because the specific storage value used in modeling, if anything, probably is lower than actual conditions not higher as stated by Mr. Jones.
- Seasonal extremes of water level declines might be overestimated by the model instead of underestimated as suggested by Mr. Jones, again, because the specific storage value used in modeling is lower than actual conditions if anything.
- Assuming that future lawns will be ½ acre or less, water level drawdown and surface water depletion may be overestimated in the model, primarily because of conservative assumptions about consumption by lawn and garden irrigation.
- To a lesser degree, conservative assumptions regarding withdrawals for domestic purposes and subsequent septic effluent returns lead to an overestimate of drawdown and surface-water depletion.
- The effects of current withdrawals probably are mostly (90 percent or more) reflected in current water levels and future effects from current withdrawals will be small relative to future withdrawals.
- Recharge from bedrock inflow is the most uncertain element of the water balance because of limited information available on conditions within the bedrock aquifer. Recharge from streams flowing from the Bridgers is much more certain and accounts for approximately half of the rate of recharge estimated in the DNRC report.

The following are my response to John Jones' detailed comments.

<u>Page 15 (first paragraph)</u>

The basis for the conceptual model proposed by Alan English is his observation that water levels in wells completed in bedrock have stable water levels. A transient model would not predict any variation in recharge in response to changes in bedrock water levels if calibrated to stable water levels.

Mr. Jones is correct that the model does not evaluate the effects of pumping on the bedrock aquifer or the effects of bedrock pumping on the alluvial aquifer. Data on the hydraulic properties of bedrock and geometry of faulting are not available and pumping from bedrock is limited to a few wells. Therefore, there is insufficient data to model the bedrock aquifer and relatively minor withdrawals from bedrock will have a small effect on water levels in the alluvial aquifer system.

The relatively stable water levels in most bedrock wells indicate that recharge from bedrock to alluvium may not vary seasonally. Overall, recharge from the bedrock aquifer is the most uncertain element of the water balance; however, again, there is insufficient data to model the bedrock aquifer and significantly improve our estimates. Further, modeling the bedrock aquifer as a constant flow boundary instead of a head-dependent boundary is conservative with respect to drawdown in the alluvial fan aquifer system predicted by transient models in the DNRC report.

Page 15 (second paragraph)

I agree with Mr. Jones that the shallow producing zone is not perched. If the alluvial aquifer system is unconfined, a gradient less than one indicates the shallow producing zone is not perched. You could have perched conditions if the lower producing zone is confined with an upward gradient. Upward flow is unlikely in this instance, so I agree the shallow producing zone is not perched.

Evidence form other wells in the CGWA indicate horizontal gradients are approximately 0.01 to 0.03. Assuming this horizontal gradient prevails at the site of the two wells, the vertical head difference would be approximately 5 to 15 feet less (120 to 130 feet). Based on these assumptions, a reasonable vertical gradient would be 0.75 to 0.80. Regardless, the magnitude of the water level difference between these two wells is evidence of the variability of properties of the alluvial-fan aquifer over short distances as stated in this paragraph.

Pages 16-24

I do not believe the number of wells with long-term water-level records collected or the frequency of those measurements are adequate to calibrate a transient model is proposed by Mr. Jones. In addition, seasonal variations in water levels are dampened with distance from the mountain front and are small in the area of greatest development potential.

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Mr. Jones states that the estimate of recharge equal to 10 percent of precipitation is “somewhat higher that seen elsewhere”, but does not provide a basis for this statement or the location of other locations he refers to. Recharge from precipitation varies considerably with location and is very hard to evaluate. The ten percent value is a common estimate and as Mr. Jones states, is a small portion of the total recharge in the model.

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Again, relatively stable water levels observed in most bedrock wells contradicts Mr. Jones’s assertion that seasonal fluctuations of inflow from bedrock are significant. Inflow from bedrock is clearly the most uncertain element of the water balance; however, I do not believe there are sufficient data to adequately model bedrock recharge to the alluvial aquifer system. In addition, modeling the bedrock as a constant flow boundary instead of a head-dependent boundary is conservative with respect to drawdowns simulated in transient models presented in the DNRC report.

<u>Page 28 – last paragraph</u>

I agree that measured and simulated water levels could have been described and illustrated better. Again, I do not believe the number of wells with long-term water-level records or the frequencies of those measurements are adequate to calibrate a transient model as proposed by Mr. Jones.

<u>Page 31</u>

The effects of ground-water pumping are independent of recharge as I have modeled recharge and, therefore, seasonal variability of recharge does not need to be modeled. Recharge to the alluvial fan from bedrock, if it is dependent on water levels in the alluvial fan, will increase with transient pumping. However, as stated previously, I do not believe there are sufficient data to model the dependence between bedrock recharge and water levels in the alluvial aquifer system. As also stated previously, relatively constant water levels in bedrock wells may indicate that seasonal variation of bedrock recharge is not significant.

Specific storage used in the model (0.00005 or $5 \times 10^{-5}\ m^{-1}$) is based on tabulated values in the book Applied Groundwater Modeling by Anderson and Woessner (1992). That book gives a range from 1.0×10^{-4} to $4.9 \times 10^{-5}\ m^{-1}$ for dense sandy gravel. The value I used is at the low end of this range. Furthermore, according to testimony by Alan English, the alluvial fan aquifer system has significant amounts of clay. Specific storage for medium-hard clay listed in Applied Groundwater Modeling is 1.3×10^{-3} to $9.2 \times 10^{-4}\ m^{-1}$. Therefore, I believe the specific storage value I used in the model, if anything, could be as much as an order of magnitude smaller than a typical value for the materials found in the alluvial fan aquifer instead of an order of magnitude higher as stated by Mr. Jones. Using Mr. Jones's argument, the result of using a <u>lower</u> specific storage value will be projection of <u>faster</u> drawdown and <u>faster</u> propagation of effects, as well as <u>more</u> seasonal water level fluctuation. In addition, by Mr. Jones's argument, <u>under</u>estimating storage coefficient will result in <u>over</u>estimating seasonal water level variations and <u>over</u>estimating local drawdown caused by ground-water pumping.

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I only removed the in-house portion of return flows in transient model 3 (contradicting a statement by Mr. Jones). Outdoor return flows were left unchanged.

I agree that the way wastewater returns are simulated in transient model #4 is not entirely realistic. Outdoor returns should have been distributed throughout the simulated development as I did in transient model 3. However, I do not believe simulating wastewater returns the way I did in transient models 1 and 2 is reasonable. A community wastewater system probably would have either a centralized community drainfield or would land-apply wastes offsite. Transient model 3 represents off-site disposal whereas transient model 4 represents a community drainfield nearby the public water supply wells. Again it would have been better to distribute the outdoor returns throughout the development and place the wastewater returns down-gradient of the wells. Regardless, I believe the predicted drawdowns or stream depletion would be only slightly different from those presented in the DNRC report.

<u>Pages 34-37</u>

Mr. Jones is correct, Figures 32-35 represent only the additional drawdown due to increased ground-water withdrawals and not future drawdown from existing withdrawals. Current conditions are not at equilibrium; however, Figure 31 demonstrates how the majority of drawdown occurs within the first few years after pumping starts. Therefore, the residual drawdown from current withdrawals probably is no more than 10 percent of the total expected when drawdown is fully realized. Furthermore, the only appreciable overlap between the effects of new and current withdrawals will occur along the northern boundary of the CGWA in the vicinity of the most recent concentrated developments.

I believe there are a number of factors that indicate withdrawals simulated in the model are greater than are actually occurring or might occur. First, consumption for lawn and garden irrigation is based on optimal crop demand estimates (i.e. no water shortages). In fact, most lawns are not irrigated to the fullest. DNRC geographic information specialists estimated irrigated acreage and intensity of use in the Gallatin Valley for 100 randomly selected parcels using infrared aerial photography. This was done for a paper titled Effects of Exempt Wells on Existing Water Rights. Average irrigated acreage was 0.93 with 49 classified as low intensity, 39 classified as moderate intensity, and 12 classified as high intensity. I conducted an analysis of irrigated acreage for the Sypes Canyon model area and estimated average lawn size to be ½ acre. I did not rate intensity, but the intensity of irrigation does vary within and nearby the CGWA. As a consequence, consumption by lawn and garden irrigation for existing use is overestimated, possibly to a significant degree, and may be overestimated if future irrigation is not high intensity. As discussed at the hearing and in the DNRC report, irrigation of larger lots will increase withdrawals proportionately.

Further, domestic use is assumed to be 250 gallons per day per household (2.5 persons per household) in the model with 12 percent returned through septic systems. Studies in Colorado indicate that actual usage probably ranges from 125 gallons per day to 190 gallons per day for the same typical household (Kimsey and Flood, 1987). Regarding the rate of returns from septic drainfields, the study submitted by the petitioners indicates 15 percent returns may be more appropriate. I disagree for the reason I stated in my oral testimony. Consumption overlying drainfields is already accounted for in the estimate of lawn and garden irrigation I used in the model. For that reason, DNRC used a value of 5 percent for domestic and wastewater consumption in the paper entitled Effects of Exempt Wells on Existing Water Rights.

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Again, Mr. Jones is correct, surface water depletion calculated by the model represents only the effects due to increased ground-water withdrawals and not the effects from existing withdrawals. Future surface water depletions are underestimated (all else being equal) as a result, but probably no more than 10 percent of consumption by recent development. However, as I discuss in the preceding paragraph, estimates of future use are conservative because optimal lawn and garden consumption is assumed.

As stated previously, I believe the storage coefficient I used is lower than the real value if anything. Therefore, I disagree with Mr. Jones's statement about the timing of surface-water depletions.

Page 38 Simulation of Drought

Mr. Jones is correct that withdrawals were not increased in the drought simulation. Again, I believe the estimates of consumption for lawn and garden irrigation used in the model are conservative because optimal conditions are assumed and evidence from the Gallatin Valley as a whole indicate that approximately much of lawn irrigation is not under optimal conditions.

Comments on: "Applicant's Brief Supporting Establishment of Controlled Ground Water Area".

- The 1.63 acre-foot limit appears to be based on DNRC guidelines of 1 acre-foot for domestic and 2.5 acre-feet per acre for irrigation. These values are high for the stated uses. Published estimates of domestic water use per household are 125 to 190 gallons per day and DEQ uses a value of 250 gallons per day when evaluating public water supplies. Using 250 gallons per day, total household domestic use is 0.28 acre-feet. In addition, using 15.52 inches for net irrigation requirement and 70 percent efficiency, total irrigation withdrawals will be 0.46 acre-feet per household. A total withdrawal for a typical household and irrigation of ¼ acre therefore is approximately 0.75 acre-feet. Based on DNRC rules, an additional amount of 0.017 acre-feet per animal unit should be added for stock use.
- Generally, the amount of irrigated acreage and the associated volume of consumption are by far the most important factors in controlling total consumption per household. Maximum pumping rate (or the number of wells on a single parcel for that matter) has little effect on water levels in other wells for a given volume of use and acreage of irrigation. In addition, uses such as indoor sprinklers for fire protection require the full 35 gpm of a standard ground water certificate.
- Administration and enforcement of a system of preferences and alternate-day watering could be cumbersome.

- Regarding the comment on whether the CGWA boundary is arbitrary or not. My statement at the hearing pertained to the hydrogeologic significance of the CGWA boundary and not whether it was a logical boundary for management purposes.

Comments on the brief of Russell Westlake, Sheryl Westlake, Sylvia Osterman, and Westlake Farms

- Opponents calculate the number of households or number of ¼-acre lawns that could be supported by 248 acre-feet of consumption used in transient models in the DNRC report. However, they do not calculate the number of homes with ¼ acre irrigation nor do they consider consumption of wastewater. Using 12 percent of there estimate of 300 gpd per household for indoor consumption and 15.52 inches irrigation requirement for outdoor consumption, approximately 680 households would consume 248 acre-feet.
- The opponents offer to install a monitoring well; however, it is unclear how monitoring data would be used. If the CGWA is made permanent, ongoing monitoring in a new well or wells on the opponents property in addition to selected existing wells would provide valuable information for future management of the CGWA.

Comments on: Written statement of Kathy Gallagher

The following are comments on the technical content of the written statement by Kathy Gallagher in favor of the petition.

- Ms. Gallagher states that recharge from small streams was estimated at 18,000 to 23,000 ac-ft/yr and that this estimate was based on one time events, take from literature from a decade ago. First, recharge from small streams was estimated at 10,626 to 10,909 ac-ft/yr. Second, the estimates of stream flow are based on streamflow measurements by prior investigators (Hackett et al, 1960; Hay, 1997) and measurements of active channel widths by Hay and DNRC using methods described by Parrett et al (1983).
- Estimates of consumption equal to 938 ac-ft/yr are based on measurements at Summer Ridge Subdivision, published guidelines for typical water use, and published reports on water consumption for household, lawn and garden, and wastewater disposal. This estimate relied on conservative assumptions and probably overestimates current consumption.
- Ms. Gallagher states “use of a steady-state model would imply that if recharge and discharge are currently balanced, any additional change in discharge, with recharge holding steady, would result in discharge (including withdrawals) exceeding recharge”. This can be said about any aquifer and, therefore has no bearing on the sustainability of development within the CGWA relative to anywhere else. That is because water is initially removed from aquifer storage when a well or wells begins to pump. Drawdown expands in all directions from the well until water levels are reduced in areas of aquifer discharge to springs or streams (usually) or where recharge was previously rejected (Theis, 1940).

Ultimately reduced discharge and/or increased recharge will balance the new withdrawal. Furthermore, a transient model was used in the DNRC report to simulate the effects of potential new withdrawals on ground-water levels in the interim before a new balance between recharge and discharge is established.

- Ms. Gallagher states that the scenario of drought and development impacts combined has not been evaluated, however, the effects would be more that the sum of each. The effects of drought and development will generally be additive to the extent that the transmissivity of the aquifer is not reduced significantly by reduced water levels. In addition, the effects of drought will be greatest along the Mountain front, but the effects of development in that area probably will be relatively minor compared to areas where additional development are likely to occur.
- Ms. Gallagher states that the final resulting water-level declines when the aquifer returns to equilibrium have not been determined. Figures 32 through 35 are the maximum seasonal water level declines when greater than 95 percent of water consumption is offset by reduced discharge at aquifer boundaries. At this point water-level drawdown has stabilized for any practical purpose.
- See my comments on Mike Jones report for discussion regarding whether the model underestimates water-level declines. In general, I believe the model is based on conservative assumptions that likely result in overestimation of declines if anything.
- Ms. Gallagher identifies 5 to 20 feet of declines in the past 10 years, up to 30 feet of declines due to a ten-year drought, and predicted 20 feet of drawdown from additional development as evidence of excessive declines. Keep in mind that the greatest declines in existing wells were in wells in Spirit Hills and Summer Ridge subdivisions, probably resulting from pumping in those areas. Further, the effects of drought would be greatest along the mountain front and the effects of new development will be concentrated in the western half of the CGWA. Therefore, the greatest existing water-level declines and greatest potential future declines due to drought and development will not occur in any one place. In other words, you can not add these values to get a total water level decline.
- Ms. Gallagher states that well development in the CGWA could result in declines in water quality in the East Gallatin River or could cause the Bozeman wastewater treatment plant that discharges to the River to exceed standards. However, she does not provide water quality data or details on the operating constraints on the wastewater treatment plant necessary to evaluate this concern.
- Ms. Gallagher states that bedrock aquifers near the mountains do not meet drinking water standards and that water users have had to haul water in the past. There are no details presented on these occurrences. Again, because of time constraints, I did not review the original petition to determine if that information is already in the file.
- Refer to my comments on the brief presented by the petitioner’s attorney for a discussion of the petitioner’s requested controls.

Comments on: Written statement of S. Craig Deaton

The following are comments on the technical content of the written statement by S. Craig Deaton in favor of the petition.

- Mr. Deaton correctly points out that aquifer materials within the CGWA are variable and poorly understood. I believe the DNRC report presents a reasonable representation of the overall properties of the alluvial fan aquifer system and the potential effects of future pumping, but it does not represent a detailed understanding of aquifer variability over short distances.
- Mr. Deaton questioned the extent of the study area for the DNRC report. As I stated in the report and at the hearing, the effects of pumping within the CGWA extend outside CGWA and recharge outside the CGWA affects water availability within the CGWA. The model had to be expanded to incorporate as many of the influences on water levels and the effects of pumping as possible.
- Mr. Deaton states that community wells could create significant drawdown at higher elevations in the more poorly understood portions of the CGWA. Transient modeling in the DNRC report indicates that will not be the case; however, applicants for community wells, it they are allowed, would need to conduct aquifer testing and analyze criteria for issuance of a water right including the potential for adverse effects to existing water users.

References

Kimsey, D.W. and P.K. Flood, 1987. Domestic consumptive use, Technical Memorandum to the Colorado State Engineer, 16 pp.

Parrett, C., R. Omang, and J. Hull, 1983. Mean annual runoff and peak flow estimates based on channel geometry of streams in northeastern and western Montana: U.S. Geological Survey Water-Resources Investigations Report 83-4046, Helena, MT, 26 pp.

Theis, C.V., 1940. The source of water derived from wells: essential factors controlling the response of an aquifer to development, Civil Engineering, V. 10, p. 277-280.