The Division of Water Resources of the Kansas Department of Agriculture (**DWR**) determined that the water right held by the U.S. Fish and Wildlife Service (the **Service**) for diversion at the Quivira National Wildlife Refuge has been impaired by junior groundwater diversions within the Rattlesnake Creek drainage basin. However, DWR and Big Bend Groundwater Management District No. 5 (**GMD5**) reached differing conclusions regarding whether a proposed field of augmentation wells would alone serve to resolve DWR's earlier impairment finding. Furthermore, the DWR and GMD5 also disagree about the sustainability of Rattlesnake Creek surface flows, the importance of reducing agricultural pumping within the Rattlesnake Creek drainage basin, and the effectiveness of proposed end-gun removals in terms of net reduction in groundwater diversion. The Water Protection Assn. of Central Kansas (**Water PACK**) asked me to provide a limited peer review of the analyses presented by DWR and GMD5 in order to devise a suggested resolution.

This brief report summarizes my understanding of DWR's and BGW's positions, as well as my proposed resolution to differences. I also suggest an alternative augmentation approach as a result. Because there has been some discussion among DWR and GMD5 about the inclusion of evaporation and pond volume filling in calculations relating to the Quivira water right, I have included a brief section below explaining pertinent aspects of that right. Finally, I discuss my opinion regarding the effectiveness of end gun removal as a component of GMD5's proposed local enhanced management area (**LEMA**). To accomplish this review, I read several documents and studied spreadsheets supplied by GMD5 and DWR, as listed in the Reference section below and referenced in this report.

Concurrence

Fortunately, DWR and GMD5 use the same hydrologic modeling tool developed by BGW for GMD5, as well as some of the same model runs. The differences between the parties do not lie in the model, its inputs, or its implementation. Nor is there disagreement regarding whether groundwater pumping within Rattlesnake Creek basin affects stream flow in Rattlesnake Creek. The primary areas of disagreement involve interpretation of model results as they relate to the Quivira water right.

DWR Position

DWR's position regarding the condition of the Rattlesnake Creek as it relates to the Quivira water right may be summarized as follows[1]:

- **Stream Flow.** Rattlesnake Creek flows measured at the Zenith gauge are trending downward while the precipitation trend is increasing.
- **Base Flow.** There will be no baseflow at Zenith by the end of the future model run (2075).
- **Augmentation Capacity.** Augmentation at 15 cfs combined with zero reliable surface flow at Zenith will be insufficient to meet 30 cfs demand of Refuge in March, April, October, and November. DWR has not considered, but has not necessarily ruled out, operation of the Little Salt Marsh to regulate available runoff, nor has DWR considered modest increases in augmentation pumping above 15 cfs that may be necessary on an infrequent, as-needed basis.

[1] Primarily based on KDA-DWR (2019a) memo: "Sufficiency of GMD 5's Augmentation-Only Plan to Resolve Quivira Impairment."

RECEIVED
May 09 2019
Big Bend GMD #5

- **Sustainability.** DWR remains concerned about long-term sustainability of the proposed augmentation plan and upwelling of saline water.
- **Curtailment.** Pumping reductions of approximately 14% or more, depending on zone[2], from 2003-2012 basin-wide average are required to "halve the rate of increase in pumping depletions to Rattlesnake Creek streamflow" and, in conjunction with augmentation, remedy the Refuge's impairment complaint (DWR, 2018b).

BGW Position

The BGW[3] position and response to DWR may be summarized as follows:

- **Stream Flow.** Rattlesnake Creek flows measured at the Zenith gauge are declining; however, model results show that declines cease in the final 17 years of a 68-year, forward-looking simulation.
- **Base Flow.** Model results show there is always some[4] baseflow at Zenith by end of run (2075).
- **Augmentation Capacity.** An augmentation field with a modest increase above 15 cfs via built-in redundancy, operated on an as-needed-basis and in conjunction with using Little Salt Marsh[5] to store and regulate the variable flow of Rattlesnake Creek, could satisfy the needs of the Refuge.
- **Sustainability.** Conceptual design of the augmentation field addresses salinity upwelling and sustainability.
- **Curtailment**. Supports GMD5 LEMA proposal (GMD5, 2019). However, BGW notes pumping reductions do little to improve water delivery to the Refuge and reduce augmentation requirements,[6] as water reduced via the most recent LEMA flows to Wichita (Balleau, 2019b).

Resolution of DWR and BGW Positions

The differences between DWR and BGW surrounding overall stream flows and base flows appear to be largely resolved. DWR appears to accept the model results showing that Rattlesnake Creek flows will eventually reach a stable condition of no further decline. However, DWR may not be satisfied with the

[2] The Rattlesnake Creek drainage basin has been divided into pumping impact zones based on hydrologic modeling results. Zone A represents the area in which groundwater pumping will eventually have a 10% or greater impact on Rattlesnake Creek flow at Zenith (that is for every 100 AF pumped within Zone A 10 AF or more will come from the flow at Zenith). Pumping in Zone B, which lies within Zone A, has an estimated ≥20% impact on flows at Zenith. Similarly, pumping in Zones C and D are predicted to have ≥30% and ≥40%, respectively, impact on flow at Zenith. (See KDA-DWR, 2018a)

[3] Based on email and telephone conversations with Peter Balleau, David Romero and Steve Silver of BGW and review of several documents (see references) they provided. This is my understanding of BGW's position. It may or may not be congruent with GMD5's position on these bullets.

[4] Modeled median baseflow for final 10 years of future Baseline A simulation is 10 cfs at Zenith (Exhibit 2, BGW, 2019). Twenty-year running average baseflow at Zenith at the end of the run is between 3 and 7 cfs (BGW, 2019b).

[5] BGW argues that since the Refuge water right includes the volume of Little Salt Marsh, it is an operational facility ("it can't be filled unless it is emptied", Balleau, 2019b) that can and should be used to store surplus flows for release during times low flow in Rattlesnake Creek and peak need by the Refuge.

[6] "The effect of cutbacks is to reduce augmentation requirements about 1.5 cfs typically and in worst years over 3 cfs." (Balleau, 2019a)

predicted eventual steady state condition of Rattlesnake Creek and, hence, call for curtailment to reduce stream depletions.

With regards to baseflows, DWR and BGW now understand and can replicate each other's calculations[7]. What DWR called "baseflow" in Figure 2 of their analysis of the augmentation only solution proposed by GMD5 (KDA-DWR, 2019a) is more correctly a flow balance curve showing that at first flood flows plus inflows less water leaking out of Rattlesnake Creek are positive and, after simulation year 2018, the balance goes negative (more water is seeping into the Rattlesnake Creek streambed than is coming out).

Regarding augmentation capacity, BGW considers the 15 cfs capacity of the proposed well field to be a nominal amount, not an absolute limit; that is, short-term augmentation pumping of 1.5 to 2.0 cfs more, coupled with operation of Little Salt Marsh to regulate the variable water supply, could address the needs of Quivira. Based on careful statements by Chief Engineer Barfield[8], and pending agreement by the Service regarding compatibility with habitat management, it appears the Little Salt Marsh could be used to a limited extent to help meet the Refuge's peak demand. I recommend considering operation of Little Salt Marsh within its top 14 inches[9], which would provide approximately 50% of its storage capacity for regulation of Rattlesnake Creek flows, while preserving more than 83% of its full-pond surface area (habitat).

Both DWR and BGW remain concerned about the sustainability of the proposed augmentation field, although BGW is more confident of success and has conceptually designed a battery with 22 wells at 304 gpm each, or 46 wells at 145 gpm each, to minimize drawdown and upwelling of saline groundwater (BGW, 2017 and 2018). Test wells should be drilled to verify the augmentation well design parameters, including water quality and the potential for upwelling of saline water. However, from a cost perspective, it may be more efficient to change existing irrigation rights within the basin to permit pumping directly to Rattlesnake Creek as an alternative to developing a new well field dedicated strictly to augmentation (see Alternative Augmentation below).

Concerning curtailment, GMD5's proposed LEMA=Zone A (GMD5, 2019), which BGW supports[10], includes 14,750 AFY from junior water user end gun removal within Zone A plus 4,000 AFY from additional

---

[7] According to BGW (telephone conversations on April 9, 2019), DWR now understands BGW's baseflow calculations and agrees there is generally some "approximate baseflow" in Rattlesnake Creek at the end of the future baseline simulation run.

[8] Teleconference discussion April 1, 2019, 2:30 PM CDT KDA-DWR (Chief Engineer David Barfield, Chris Beightel, Sam Perkins, Lane Letourneau, KDA Chief Counsel Kenneth Titus), Andrew Keller, Micah Schwalb (counsel for Water PACK), and Patrick Janssen (Water PACK secretary).

[9] Operation of Little Salt Marsh within its top 14 inches, between elevation 1,781.8 and 1,783.0 feet above sea level, would result in a minimum surface area of 713 acres and storage volume of 937 AF (compared to full-pond area of 864 acres and volume of 1,865 acre-feet). Little Salt Marsh elevation, surface area, and storage volume from equations by Jain (1998).

[10] Note, BGW is not advocating augmentation only and I (Andrew Keller) cannot tell where the augmentation only concept came from or when it started as it is not in the record shared with me by BGW, nor did BGW argue for augmentation only in our April 9, 2019 telephone discussions. DWR (2019a) does quote GMD5's assertion "the model irrefutably shows that augmentation can solve the impairment complaint (and ultimately becomes sustainable)" but I have not studied the actual email to get the full context. I do note BGW has consistently stated

conservation within Zone D. These pumping reductions are close to the quantities DWR presented in its December 11, 2018 meeting with Water PACK that would be required to reach its goal "to halve rate of increase of depletions" (DWR, 2018b).

However, solutions that do not address the underlying difficulties in the Rattlesnake Creek basin may serve to treat only those chronic issues presented by continued over-appropriation. BGW's modeling work nevertheless demonstrates that augmentation coupled with operation of Little Salt Marsh would largely relieve difficulties at Quivira. By contrast, corrective controls involving stringent and ineffective pumping cuts would disrupt the economic vitality of the region. The challenge, therefore, is to design a remedy which addresses the root cause of the controversy with minimal impact to all water users in the Rattlesnake Creek subbasin.

DWR's stated goal is "halving the rate of increase in pumping depletions to Rattlesnake Creek streamflow." While DWR may have a clear concept of what this statement means, I find it confusing, subject to interpretation, and somewhat arbitrary. Furthermore, if we only look at the impact of pumping cutbacks on flow of the Rattlesnake at the Zenith gauge, we minimize their potential value. Corrective controls that include end gun removal, net of return flows, should be considered as direct offsets to the hydrological calculations. What's more, even if water does not appear in Rattlesnake Creek at the Zenith gauge, it is not extracted from the basin and should be fully credited towards achieving the goals set forth by GMD5 and DWR. This leads to an alternative approach to augmentation.

Alternative Augmentation

The current augmentation plan (future augmentation well field south of the Refuge) on average would pump 15 cfs one third of the time, 5 to 6 cfs one third of the time and be off one third of the time. Some years no augmentation is anticipated. Modeled total annual required augmentation (with Little Salt Marsh operation) without LEMA pumping cutbacks is approximately 5,000 AFY on average and with LEMA pumping cutbacks would be approximately 3,500 AFY. What's more, a new, dedicated well field with 15+ cfs pumping capacity that is idle much of the time is an expensive and, in a way, inefficient augmentation solution.

An alternative would be to use existing irrigation wells within the Rattlesnake Creek basin and discharge directly to Rattlesnake Creek. Some seepage loss would have to be accounted for in order to enhance stream flows to the Refuge, but the seepage would build groundwater mounds associated with Rattlesnake Creek and improve flow conditions[11]. Participating wells could be on call for augmentation and irrigation allowed in years/seasons when antecedent conditions were such that augmentation need was not anticipated. Likewise, because the Refuge's peak demand months (March, April, October,

---

pumping cutbacks are not very effective at reducing the magnitude of impairment and that augmentation slightly greater than 15 cfs on an as-needed basis in conjunction with operation of Little Salt Marsh could meet Refuge water demands without requiring irrigation pumping cutbacks.

[11] However, the resulting higher water table associated with pumping directly into the Creek would likely result in more evapotranspiration loss from the Creek, which would also have to be compensated, highlighting the importance of invasive tree species removal. Note stream losses would be approximately equal to the irrigation return flow percentage, so the net pumping effect on the aquifer would be the same as with irrigation, but the depletion from the basin would be reduced by the amount of the consumptive irrigation reduction.

November) are in low-irrigation demand months, augmentation could be accommodated on-demand and offset later. Wells could also be on a rotational basis such that some wells were used for augmentation some years and others other years, or a field was cut in half (part circle) to allow half the area to be irrigated and half the pump/well capacity for augmentation. Note that such augmentation effectively results in a 100% of the irrigation pumping reduction directly and immediately increasing the flow in Rattlesnake Creek rather than only a fraction (e.g. ≥ 40% within Zone D) reaching the creek after a period of years. This would allow augmentation to be on-demand and the associated irrigated land fallowing to be adaptive. The primary cost would be the cost of pipelines from existing participating irrigation wells to Rattlesnake Creek. As little pressure is required, low-cost, low-pressure pipe (e.g. ADS) could be used for conveyance to Rattlesnake Creek.

Any efforts to increase Rattlesnake Creek flows at Zenith, whether by direct augmentation or other, will be more effective if invasive tree species along the creek and its tributaries are removed, as planned in GMD5's proposed LEMA. Reducing the consumptive use associated with invasive species would enhance baseflow and water conveyance.

Refuge Water Right

"The Refuge's water right entitles it to take water from Rattlesnake Creek at three points of diversion at a combined maximum diversion rate not in excess of 300 cubic feet per second and a quantity not to exceed 14,632 acre-feet of water per calendar year for recreational use. This is the volume of water used in 1987 to operate the wetlands areas including filling Little Salt Marsh (1,865 acre-feet), evaporation from Little Salt Marsh (2,592 acre-feet), and filling the Refuge's management areas to meet wildlife feed crop demands (10,175 acre-feet). " (Page 19 and 20 of DWR's final impairment report Barfield, 2016)

Some have questioned summing the diversion of 10,175 AFY, volume to fill Little Salt Marsh (1,865 AF), and evaporation from Little Salt Marsh (2,592 AFY) to arrive at the total annual water right for the Refuge of 14,632 AFY. Indeed, the filling and evaporation associated with storage are typically included within the diversion right. However, my understand of the 10,175 AF diversion in 1987 (year of record) is that it was measured downstream of Little Salt Marsh; and, according to DWR[12], Little Salt Marsh was empty at the beginning of 1987 and full at the end. I express no opinion on this calculation at this time.

Effectiveness of End Gun Removal

Pressure regulated sprinklers are common practice[13] in the Rattlesnake Creek basin, so we would expect the irrigation application rate (gpm per irrigated acre) to be about the same after end gun removal as before removal. Therefore, the anticipated effect of end gun removal would be a reduction in irrigated area[14] and a reduction in pumping equivalent to the flow rate of the removed end guns. However, DWR's analysis of the effect of end gun removal from 45 center pivots within the proposed Rattlesnake Creek LEMA (Zone A) under the 2010 Agricultural Water Enhancement Program (AWEP) indicates that "when adjusted for climate, the reported water use and predicted water use were nearly the same. This suggests

[12] April 1, 2019 teleconference with DWR.

[13] Personal email communication with Richard Wenstrom and Patrick Janssen April 24, 2019.

[14] This is indeed the case for the 45 center pivots with end gun removal under the 2010 AWEP in which the average center pivot irrigated area with end guns was 127.6 acres and without end guns 121.2 acres, a 5% area reduction.

that the irrigated area reduction under AWEP had no discernable impact on water use in Zone A." (Perkins, Barfield and Beightel, 2019)

Two explanations for DWR's unexpected result come to mind:

1) Something is likely wrong with DWR's climate-based water use model, its application, or interpretation; or
2) Over-irrigation (more water applied than required)[15] after end gun removal.

DWR's f7(ET,P) model (Perkins, et al., 2018) appears robust with significant coefficients, low standard error, and high R^2. But I do have questions regarding the model and its application:

- The coefficient for May ET is negative (Table T.2, Perkins, et al., 2018), indicating the greater ET is in May, the less the annual pumping. How is this explained?
- Model estimated use for 2012 appears to be missing. Is that the case or was the estimated use in 2012 exactly between that for 2011 and 2013?
- How does the calibration for the 45 AWEP pivots compare to the f7(ET,P) model for the Zone A (Perkins, et al., 2018)?
- What are the irrigated acres by year (2000 – 2017) and what are the associated pumping amounts per acre (i.e. depth) for the 45 AWEP pivots in aggregate and what is the range in pumping per acre for each year? How does this compare to the model estimated pumping depth for Zone A by year?
- The f7(ET,P) model estimated water use for all areas is close to the reported use in 2011 and the estimated error for 2011 is less than for four other years (Perkins, et al., 2018). Yet in the report on the impact of the AWEP end gun removal (Perkins, Barfield and Beightel, 2019) the estimated water use in 2011 is significantly greater than the reported use. Rather than attributing the difference to the effect of end gun removal, the report states, "this is likely due to the extremely dry conditions in 2011 that saw water use limited by authorized quantity and in some cases by the inability of some irrigation systems to provide the rate needed to keep up with crop demand." How is this the case for the 45 AWEP pivots with end gun removal and not the case for GMD5 or the LEMA, Zone A and Zone D subareas?

Notwithstanding the above questions, it is interesting to note that most of the May-September climate variability is in precipitation and ET relatively constant (Tables T.4, and T.5, Perkins, et al., 2018). Yet, looking at the regression coefficients, irrigation pumping is 5 to 6 times more sensitive to ET than to precipitation (Table T.2, Perkins, et al., 2018). This suggests when it is hot, operators are likely to irrigate, even when rain is in the forecast and could easily end up over-irrigating in wetter years. This is what I suspect could have happened in the very wet May-September of 2013 (precipitation 20.4 inches versus 2000-2016 seasonal average of 16.6 inches of rainfall). Similarly, over-irrigation could have occurred in the wet years of 2014 and 2016.

[15] Due to the prevalence of sprinkler pressure regulators, the irrigation application rate is unlikely to have changed with end gun removal. Therefore, to apply more water, there would have to be more irrigation hours per year.

Over-irrigation would result in more deep percolation returning to the aquifer. DWR's climate-based, water use model estimates gross pumping and not actual consumptive use or net pumping (gross pumping minus return flow to the aquifer). Unless there was deficit irrigation with end guns[16] and less deficit irrigation without end guns, the climate-adjusted actual consumptive use per irrigated acre should be the same with or without end guns. Thus, since the irrigated area is less after end gun removal, the net pumping should be less by at least a proportionate amount (≥5%)[17].

All else being equal, one could reduce net pumping through a range of corrective controls, including those contemplated by the LEMA. Overall, however, it is far easier to measure effects on actual pumping than consumptive use. The analysis also becomes more complicated with climate variability and future uncertainty. I therefore remain hopeful an agreement can be reached on a LEMA that achieves the mutual goals of remedying the Quivira controversy while sustaining viable irrigated agriculture in the Rattlesnake Creek basin for generations to come.

***

[16] On the April 1, 2019 teleconference with DWR, Chief Engineer Barfield said there was no deficit irrigation.

[17] There would be some additional incidental losses (e.g. spray, wind drift, evaporation) associated with any increased over-irrigation post end gun removal. However, because of the higher consumptive use fraction under end guns, any increase in incidental losses would likely be more than offset by the end gun removal.

References

Balleau Groundwater, Inc. (2010). "Hydrologic Model of Big Bend Groundwater Management District No. 5." Consultant report prepared for Big Bend GMD #5. June 2010.

Balleau Groundwater, Inc. (2017). "Augmentation Assessment." Presentation to GMD #5. August 9, 2017.

Balleau Groundwater, Inc. (2018). "Hydrology of Rattlesnake Creek Local Enhanced Management Area (LEMA)." Presentation to the Big Bend Groundwater Management District. February 15, 2018.

Balleau Groundwater, Inc. (2019a). "Exhibits 1 through 8." Prepared for GMD5. January 24, 2019.

Balleau Groundwater, Inc. (2019b). "Rattlesnake Creek computed streamflow and components at Zenith base case 1960-2075 (20-year running average)." Prepared for GMD5. February 13, 2019.

Balleau Groundwater, Inc. (2019c). "Hydrologic Issues Pending for LEMA (Local Enhanced Management Area) to Remedy Quivira Impairment." Letter from Peter Balleau to Orrin Feril (Manager GMD5). February 20, 2019.

Balleau Groundwater, Inc. (2019d). Excel workbook titled QNWR.Backup.xlsx summarizing hydrology model runs to estimate Quivira NWR impairment. Contains some of the same tables and figures used in KDA-DWR impairment documents and presentations. Received via email from David Romero to Andrew Keller. February 28, 2019.

Balleau, P. (2019a). "Question of augmentation and baseflow." Email to Orrin Feril (Manager GMD5). January 24, 2019.

Balleau, P. (2019b). Email to Orrin Feril (Manager GMD5) discussing operation of Little Salt Marsh in conjunction with augmentation. January 25, 2019.

Balleau, P. (2019c). "DWR Baseflow at Zenith." Email to Orrin Feril (Manager GMD5). February 13, 2019.

Barfield, D.W. (2016). "Final Report of the Chief Engineer, Prepared pursuant to K.A.R. 5-4-1 Concerning a Claim of Water Right Impairment, In the Matter of Water Right File No. 7571, Owned and operated by U.S. Fish and Wildlife Service." Chief Engineer, Kansas Department of Agriculture- Division of Water Resources. July 15, 2016.

Barfield, D. (2018). "Quivira Impairment Remedy Requirements." Presentation to GMD5 annual meeting by Chief Engineer, Kansas Department of Agriculture–Division of Water Resources. February 15, 2018.

Barfield, D. and C. Beightel. (2018). "Using climate-based water use estimation to evaluate the performance of efforts to reduce water use in the proposed GMD5 LEMA area 2020-2024." Kansas Department of Agriculture–Division of Water Resources. May 9, 2018.

GMD5 (2019). "Request for Quivira NWR LEMA Submitted to the Chief Engineer, Kansas Department of Agriculture – Division of Water Resources. Big Bend Groundwater Management District No. 5. February 21, 2019.

Jian, X. (1998). “Simulation of Canal and Control-Pond Operation at the Quivira National Wildlife Refuge, South-Central Kansas.” U.S. Geological Survey Water-Resources Investigations Report 97-4289. Prepared in cooperation with the Kansas Geological Survey. 1998.

KDA-DWR. (2014). “Rattlesnake Creek Basin Modeling Scenarios.” Slide deck prepared by Kansas Department of Agriculture–Division of Water Resources. November 4, 2014.

KDA-DWR. (2015). “Quivira Initial Impairment Investigation Report Presentation.” Slide deck prepared by Kansas Department of Agriculture–Division of Water Resources. St. John, Kansas. December 10, 2015.

KDA-DWR. (2018a). “Rattlesnake Creek Streamflow Response Region.” Kansas Department of Agriculture–Division of Water Resources. February 14, 2018.

KDA-DWR. (2018b). “Quivira Impairment Summary,” Draft for discussion with Water PACK prepared by Kansas Department of Agriculture–Division of Water Resources. December 11, 2018.

KDA-DWR. (2019a). “Sufficiency of GMD 5’s Augmentation-Only Plan to Resolve Quivira Impairment.” Memo prepared by Kansas Department of Agriculture–Division of Water Resources. January 4, 2019.

KDA-DWR. (2019b). “Resolving the Quivira Impairment.” Information page prepared by Kansas Department of Agriculture–Division of Water Resources. January 2019.

Perkins, S. (2019a). “Streamflow separation into baseflow and runoff components for Rattlesnake C at Zenith.” Kansas Department of Agriculture–Division of Water Resources. March 18, 2019.

Perkins, S. (2019b). “Streamflow separation tests.” Kansas Department of Agriculture–Division of Water Resources. March 29, 2019.

Perkins, S., et al. (2018). “An improved water use estimator applied to GMD5 and subareas, 2000-2016 climate and procedures: a regression relationship of groundwater irrigation water use to precipitation and ET.” Kansas Department of Agriculture–Division of Water Resources. May 9, 2018.

Perkins. S., D. Barfield and C. Beightel. (2019). “Evaluation of the impact of end gun removal on water use within GMD 5 under its 2010 AWEP.” Kansas Department of Agriculture–Division of Water Resources. January 4, 2019.