TECHNICAL MEMORANDUM

To File GMD #5/RATTLESNAKE CREEK January 4, 2018

From Dave M. Romero, P.H. and Steven E. Silver, GISP

Subject DRAFT LEMA DOCUMENT (12/19/2017) - MODEL FILES AND ANALYSIS

Introduction

On December 19, 2017, Big Bend Groundwater Management District (GMD) #5 provided a DRAFT Local Enhanced Management Area (LEMA) document to Kansas Department of Agriculture Division of Water Resources (KDA-DWR) (hereafter "DRAFT LEMA document"). KDA-DWR requested additional information on December 21, 2017. Balleau Groundwater, Inc. (BGW) was directed by GMD #5 legal counsel to provide model files associated with the DRAFT LEMA document as requested by KDA-DWR. The correspondence (12/21/17) from Kenneth Titus, Chief Counsel of KDA to Lynne Preheim, Legal Counsel to GMD #5 (attached) refers to model runs described at specific lines (numbered) of the LEMA document. An additional email message (12/22/17) from Mr. Titus to Mr. Preheim forwarded a letter from Chief Engineer Barfield with further comments and a copy of the DRAFT LEMA document with the referenced line numbers (also attached). This technical memorandum responds to the December 21 message by describing the format of the model scenarios examined with reference to those specific (Item 4) numbered lines for ease of use by KDA-DWR.

The description of model runs presented in this document is intended to provide general details of the technical analyses that support the DRAFT LEMA document. If needed, BGW is available for technical coordination with KDA-DWR to discuss the analyses at a greater level of detail than is presented herein. A link to the model files is attached to this document. The model files are categorized into Scenarios A and B and Scenarios 1, 2 and 3.

A clarification on pumping reductions with regard to consumptive use (CU) should be noted. The DRAFT LEMA document refers to a pumping reduction from end-gun removal totaling 18,982 acre

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Big Bend GMD #5

feet per year (AFY). That reduction translates to a CU reduction of approximately 16,500 AFY as represented in the model.[1] An additional pumping reduction of 3,500 AFY CU is also described in the DRAFT LEMA document in the focused area 5 to 10 miles around St. John. That quantity is associated with a pumping reduction of 4,000 AFY. For the remainder of this document, we refer to CU quantities for consistency. That is, end gun removal translates to a pumping reduction of ~16,500 AFY CU and the additional pumping reduction around St. John is ~3,500 AFY CU. A description of the model scenarios in the context of line numbers in the DRAFT LEMA document is below.

a. At 128-130 (p. 4) and b. At 131-133 - Pumping Reduction Analysis

On June 19, 2017, KDA-DWR provided a set of model files to GMD#5 related to preliminary analysis of pumping reductions in a defined Zone A. The initial set of KDA-DWR files represented pumping reductions of 10, 20 and 30 percent within Zone A. A later set of KDA-DWR files represented a pumping reduction of 15 percent within a refined Zone A. BGW interprets the 15 percent pumping reduction simulation by KDA-DWR to reduce the future growth in depletion at Zenith gage by half, which is consistent with the objective of the DRAFT LEMA document. Accordingly, BGW used the flow at Zenith gage in the 15 percent reduction simulation as a constraint for determining the pumping reduction needed to meet the objective of the LEMA document. That is, BGW first ran the model (Scenario A) with the water-use reduction associated with end-gun removal (~16,500 AFY CU) and found the future growth in depletion at Zenith will be lessened, but will not reduce the future growth in depletion by half. We then iteratively ran the model (Scenario B) to determine that an additional ~3,500 AFY CU reduction is needed in the high impact area around St. John (DRAFT LEMA document Attachment 3) to attain the targeted halving of future depletion trends. BGW used the same format of model files originally produced by KDA-DWR, but with adaptations to reflect the pumping reductions in Scenarios A and B described above. The link to the model files includes a directory structure with Scenarios A and B separately organized.

[1] Consumptive use herein is groundwater diversion less irrigation return flow. The model represents variable irrigation return flow depending on variation in hydrologic conditions (i.e wetter or drier than average conditions). Accordingly, a pumping reduction of 18,982 AFY is approximately a reduction of 16,500 AFY in CU.

c. At 220-222 (p. 6) - Pumping Reduction and Augmentation Pumping Analysis

BGW adapted the GMD #5 model files to facilitate the analysis of augmentation pumping. The adaptations do not materially change the results that would have been derived from the original model; they provide flexibility in use of the model for analysis of augmentation pumping. The adaptations include: 1) refinement of solver parameters, 2) conversion of pumping wells represented with the MNW1 package to the WEL package, and 3) representing the augmentation wells with the MNW2 package. The analysis involved running a series of three scenarios with the adapted model files. The link to the model files includes a directory structure with Scenarios 1, 2 and 3 separately organized as described below.

1. Baseline A,
2. Baseline A with the reduction in pumping (end-gun removal) totaling ~16,500 AFY CU plus an additional reduction of ~3,500 AFY CU in the High Impact Area around St. John.
3. Baseline A with the reduction in pumping totaling ~16,500 AFY CU plus an additional reduction of ~3,500 AFY CU in the High Impact Area plus augmentation pumping at the Conceptual Augmentation System (46 wells, Attachment 5 of the DRAFT LEMA document). Simulated flow at Zenith gage from Scenario 2, in conjunction with Refuge demand[2], is the basis for formulation of the example augmentation pumping schedule.

The sources of water supporting the augmentation wellfield (from a regional budget perspective) are listed on Table 1 (average over 58 years). The values in Table 1 are derived by calculating the flow-budget difference between Scenarios 2 and 3.

Table 1. Average 58-Year hydrologic budget change from augmentation pumping (AFY).

	Augmentation Pumping	Aquifer Storage	ET	Stream Leakage (Outside RSCB)	Stream Leakage (Inside RSCB)
End Gun Removal (~16,500 AFY CU) and Additional ~3,500 AFY CU Cut	4260	-450	-2750	-940	-120

Drawdown to the shallow aquifer resulting from augmentation pumping is shown on Attachment 6 of the DRAFT LEMA document. There is also a water-level rise regionally within the proposed LEMA area resulting from the reduction in pumping from end-gun removal (~16,500 AFY CU)

[2] Refuge demand is described in Attachment 5 of the Final Report of the Chief Engineer (Barfield, 2016).

and the additional reduction in pumping within Zone D (~3,500 AFY CU). The water-level changes on Attachment 6 of the DRAFT LEMA document are derived by taking the difference in water levels between Scenarios 1 and 3 after a projection of 58 years.

d. At 298-301 (p.8) - Water Quality Analysis

BGW estimates specific conductance of groundwater at the area of the conceptual wellfield is approximately 2,000 µS/cm. Combining the volume of augmentation water with a regression of flow to specific conductance at the Zenith gage allows water quality to be estimated. That is, the resultant mix of augmentation water with river water can be estimated. Projected water quality, in terms of specific conductance, is shown on Figure 1. The regression of flow to specific conductance is based on data from Zenith gage during the period from Nov 1998 to Dec 2003 when water quality data was collected in real time. BGW anticipates water quality can be managed based on the requirements of Refuge staff by adjusting the degree of fresh water provided with redundant capacity of actual wells with varying water quality.

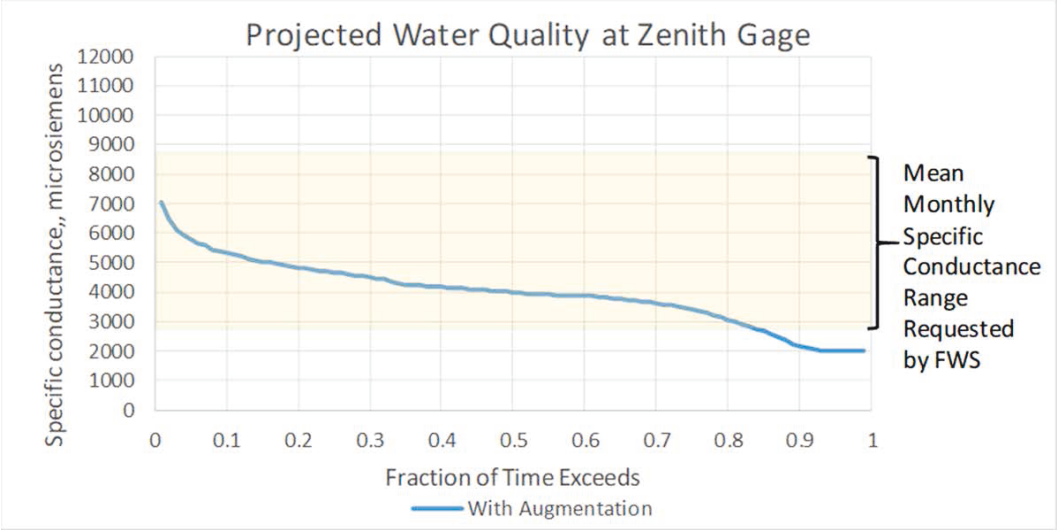

Figure 1. Estimated water quality at Zenith gage in 58-year projected simulation.

BGW incorporated particle tracking to assess water quality changes associated with potential vertical and horizontal migration of variable quality water associated with augmentation pumping. The

analysis involves scenarios 1 and 3 with the addition of reverse particle tracking. General specifications for the simulations are listed below.

i. Augmentation wells (46) are simulated in model Layer 1 at the locations of the conceptual augmentation system (Attachment 5 of the DRAFT LEMA document). Each well pumps at a rate up to 150 gpm, which reflects a total wellfield capacity of 15 cfs.

ii. Model layers 1 and 2 represent the shallow and deep portions of the main aquifer; Layer 3 is the bedrock. Particles are placed in model Layers 1, 2 and 3 in the area of the conceptual wellfield. The particles are simulated in reverse mode in Scenarios 1 and 3.

iii. Displacement of the particle endpoints is analyzed in the two scenarios. For example, comparing particle endpoints in Scenario 1 with Scenario 3 enables examination of the migration of augmentation water to the conceptual augmentation wells. The wellfield source water can then be evaluated to determine whether it moves through the saltwater interface that exists where the main aquifer is in direct hydraulic communication with the deeper Permian bedrock.

Kansas Geological Survey (KGS) studies have established that groundwater in the main (unconsolidated) aquifer in the eastern portion of GMD #5 is naturally intruded by saltwater from the underlying Permian bedrock (Young, 1992; Whittemore, 1993; Buddemeier, 1994; Garneau and others, 1994). One of the studies (Buddemeier, 1994, Figure A5) describes characterization of a salt water

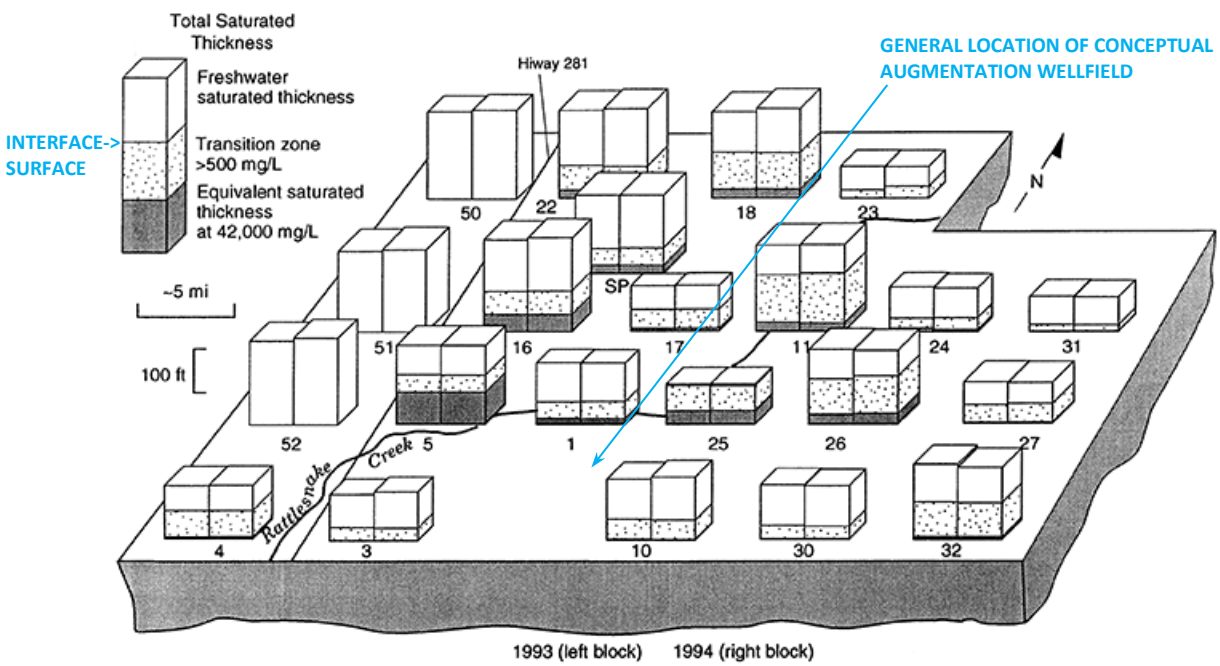

Figure 2. Conceptual illustration of well water columns and saturated thickness of aquifer affected by saltwater intrusion from deeper bedrock (adapted from Buddemeier, 1994).

interface between shallow fresh water and a transition zone to the deeper groundwater affected by flow from Permian bedrock. Figure 2 illustrates the layout of the well water column data used to classify the thickness of fresh groundwater above an example *transition zone* defined by the elevation of the 500 mg/L chloride concentration. We developed a surface characterizing the elevation of the interface between the fresh water and that transition zone and incorporated the particle tracking analysis to evaluate the potential for water quality degradation caused by augmentation pumping. Herein we refer the interface between the fresh water and the transition zone as the base of the fresh water zone.

The analysis approach is two-fold. First, we examine how many particles originate from or move through the transition zone into the shallow groundwater area representing source water to the augmentation wellfield, but without any augmentation pumping (Scenario 1). Second, we examine the particles with augmentation pumping (Scenario 3) and quantify how many more particles originate from or move through the transition zone. The change in particle flow, induced by augmentation pumping, provides a basis to estimate a generalized concentration change to the shallow source water where the augmentation wellfield is planned to be completed.

The analysis is illustrated on Figures 3 and 4. Figure 3 shows a perspective view of both the vertical and horizontal displacement of the particles in scenarios 1 and 3. The orange particles represent Scenario 1 (Baseline). The blue particles illustrate the variation in particle paths when the augmentation

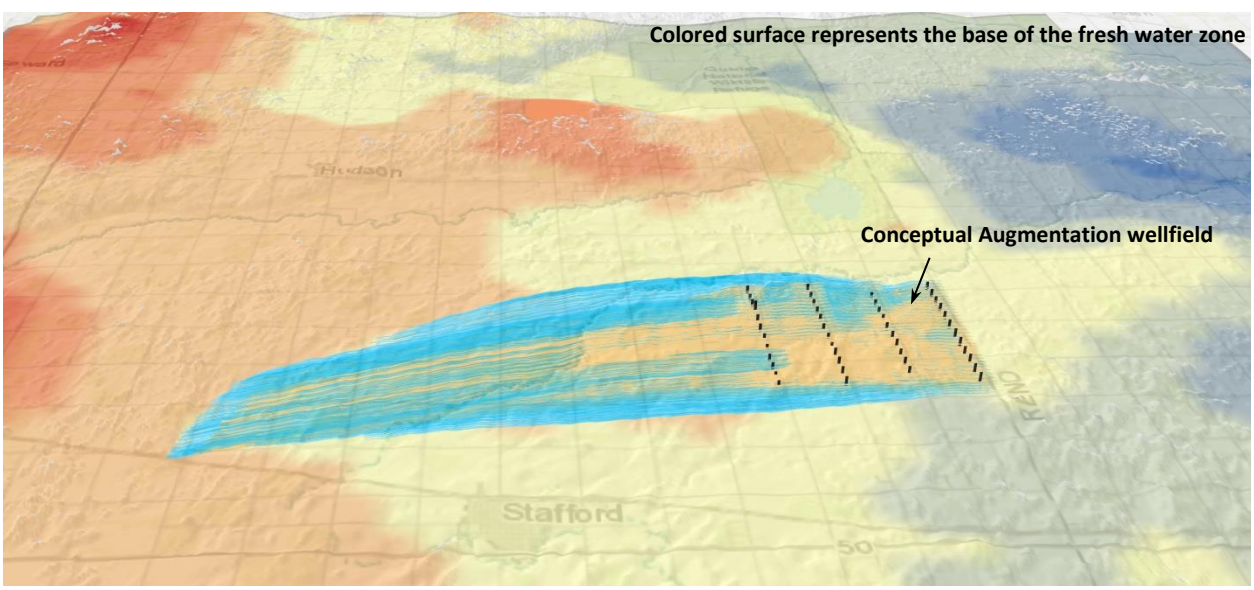

Figure 3. Particle displacement in Scenarios 1 (orange) and 3 (blue) representing source water migration to the augmentation wells. View is from above the base of the fresh water zone.

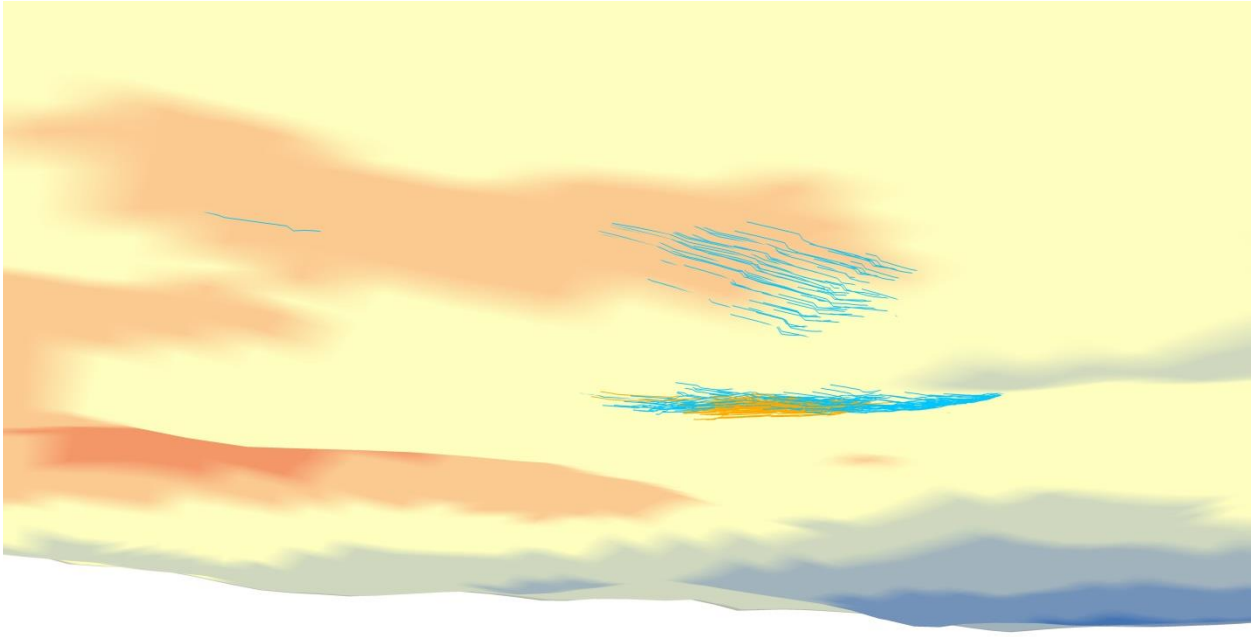

Figure 4. Particle displacement in Scenarios 1 (orange) and 3 (blue) representing source water migration to the augmentation wells. View is from beneath the base of the fresh water zone. Particle paths displayed either originated from or passed through the transition zone to become source water to the augmentation wells.

wells are online in Scenario 3. The principal source of water for augmentation is derived from the west (upgradient) area. The color tones on Figure 3 represent the subsurface elevation of the base of the fresh water zone. The warm (red and yellow) tones represent higher elevations (of that surface) than the cooler (blue) tones. The pertinent assessment involves quantifying the number of the particles representing source water to the augmentation wells that either originate from or migrate through the transition zone. Figure 4 shows a worm's-eye view from beneath the surface of the interface between the fresh water and the transition zone, which highlights the augmentation well source-water particles that travel through or originate from the transition zone.

A generalized fresh water quality area in the Layer-1 grid cells representing the augmentation wells contains 3,000 particles at the end of the 68-year simulation. Without augmentation pumping, 95 of them (3.2 percent) originate from or migrate through the transition zone (orange particles); with augmentation, the particle count of 95 increases to 164, or 5.5 percent of the 3,000 (blue particles) originate from or migrate through the transition zone. That is, the augmentation pumping affects the generalized fresh water quality area on the order of 2.3 percent (an increase from 3.2 to 5.5 percent).

Figures 3 and 4 conceptually illustrate shallow fresh water ingress to the wells at a higher rate and volume which dominates and dilutes smaller upward migration from saline bedrock sources. However, site-specific observation, testing and more localized model analyses will be necessary to evaluate actual operational trends in water quality. Well depths and screens should be planned to attain intended capabilities for yield and quality.

Analysis of augmentation at 231. (p. 6)

The model scenarios described above, and the associated model files, inherently include information with regard to wellfield location, wellfield capacity, pumping and delivery rate, water quality and delivery frequency. BGW is available for technical coordination with KDA-DWR to discuss specific details. In the analysis herein, BGW did not attempt to simulate water use operations at the Refuge. That is, the delivery location for simulation augmentation water is assumed to be at Rattlesnake Creek at the boundary of the Refuge (as depicted on Attachment 5 of the DRAFT LEMA document) without simulation of augmentation water flowing within the Refuge boundary.

Attachments: Email from Lynn Preheim, Esq. to Peter Balleau, P.G., 12/21/17
Email from Lynn Preheim, Esq. to Peter Balleau, P.G., 12/22/17
Model Files:
https://drive.google.com/open?id=1dQ7ATBXsWA8haSNlCTxLR93B2oTUY6qV

References

Barfield, D., 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. 7,571, Owned and Operated by U.S. Fish and Wildlife Service: Kansas Department of Agriculture, Division of Water Resources.

Buddemeier, R.W., 1994, Overview and Summary of FY94 Mineral Intrusion Studies: a cooperative investigation by the Kansas Geological Survey and Big Bend Groundwater Management District No. 5, Kansas Geological Survey Open-File Report 94-28a.

Garneau, G.W., Buddemeier, R.W. and Young, D.P., 1994, Characterization of the Saltwater Interface and Related Parameters: a cooperative investigation by the Kansas Geological Survey and Big Bend Groundwater Management District No. 5, Kansas Geological Survey Open-File Report 94-28b.

Whittemore, D.O., 1993, Ground-Water Geochemistry in the Mineral Intrusion Area of Groundwater Management District No. 5, South-Central Kansas: Kansas Geological Survey Open-File Report 93-2.

Young, D.P., 1982, Mineral Intrusion: Geohydrology of Permian Bedrock Underlying the Great Bend Prairie Aquifer in South-Central Kansas: Kansas Geological Survey Open-File Report 92-44.

EMAIL ATTACHMENTS

Dave Romero <dromero@balleau.com>

FW: Rattlesnake LEMA Data Request

Preheim, Lynn <lynn.preheim@stinson.com> Thu, Dec 21, 2017 at 12:11 PM
To: Orrin Feril <oferil@gmd5.org>, Peter Balleau <peterballeau@balleau.com>

See below.

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From: Titus, Kenneth [KDA] [mailto:Kenneth.Titus@ks.gov]
Sent: Thursday, December 21, 2017 12:59 PM
To: Preheim, Lynn
Subject: Rattlesnake LEMA Data Request

Lynn,

Can you or GMD 5 staff please provide us with all of the necessary data that backs up the claims in your proposed management plan, including but not limited to the end gun database, model runs, augmentation analyses, and any data used to support claims of water savings and the methodologies used for evaluating those claims.

Specifically, this would include the following data:

1. End gun database referenced at line 112. (p. 3)
    a. Including the endguns referred to in lines 121-123 and (p. 3-4)
    b. Including the water use for those systems at line 124 (p. 4)
2. Historical water use of end gun systems at 120. (p. 3)
3. All bases of assuming that 10% of the water put through a center pivot system with and end gun goes out the end gun at 127. (p. 4)
4. Model runs:

    a. At 128-130 (p. 4)
    b. At 131-133 (p. 4)
    c. At 220-222 (p. 6)
    d. At 298-301 (p. 8)
4. Analysis of augmentation at 231. (p. 6)

Other items may arise as we work through this data and the proposed management plan. Let me know if you have any questions about our request.

Kenneth B. Titus | Chief Counsel

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Dave Romero <dromero@balleau.com>

Fwd: Comments on Rattlesnake LEMA

1 message

Preheim, Lynn <lynn.preheim@stinson.com> Fri, Dec 22, 2017 at 12:24 PM
To: Orrin Feril <oferil@gmd5.org>, Peter Balleau <peterballeau@balleau.com>

From: "Titus, Kenneth [KDA]" <Kenneth.Titus@ks.gov<mailto:Kenneth.Titus@ks.gov>>
Subject: Comments on Rattlesnake LEMA
Date: 22 December 2017 12:49
To: "Preheim, Lynn" <lynn.preheim@stinson.com<mailto:lynn.preheim@stinson.com>>
Cc: "Barfield, David [KDA]" <David.Barfield@ks.gov<mailto:David.Barfield@ks.gov>>
Lynn,

Attached is a letter directed to the GMD 5 Board and our initial comments regarding the proposed management plan. Please provide to the Board and coordinate appropriately to provide a response.

We have also made good progress regarding the relationship between precipitation and irrigation and expect to have this data to you in early January. Please let me know if you have any questions. I'll be out of the office most of next week, but will still be checking emails if anything comes up.

Have a Merry Christmas!

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2 attachments

Letter to GMD5 Board 122217.pdf
63K

Comments on Rattlesanke LEMA DRAFT.PDF
4516K