Memo

Adaptive Resources, Inc.

To: POAC Technical Committee

From: Thad Kuntz, P.G. and Jason Yuill

CC:

Date: 4/5/2018

Re: DRAFT – Municipal Pumping Analysis, Robust Review Task: Municipal Pumping – Processes and Data Flow

INTRODUCTION

Adaptive Resources, Inc. (ARI) is completing modifications to the baseline model run of the Western Water Use Management Modeling (WWUMM) under Task 1 of the Robust Review Project Analysis (RRPA). This task includes incorporating the observed municipal pumping information into the WWUMM and will be utilized in Task 6 where the observed pumping information will be compared with the calculated baseline pumping information of municipalities throughout North Platte Natural Resource District (NPNRD) and South Platte Natural Resource District (SPNRD). The municipalities represented within the modeling in NPNRD include Bayard, Bridgeport, Broadwater, Gering, Henry, Lyman, Minatare, Mitchell, Morrill, Oshkosh, Scottsbluff, Terrytown, and the Western Nebraska Joint Water Board (WNJWB) which is a joint water supply group composed of Henry, Lyman, and Morrill starting in 2012.The municipalities represented in the modeling within SPNRD include Big Springs, Bushnell, Chappell, Dalton, Dix, Gurley, Kimball, Lodgepole, Potter, and Sidney.

PUMPING DATA

Pumping records became available from the various municipalities between 2001 and 2006. **Table 1** in Appendix A describes each full-year that metered pumping information was available for each municipality. The format of the metered pumping data varied between municipalities and in some cases within individual municipality's monthly datasets. The following list describes the formats of the pumping data adapted for this analysis:

- Monthly pumping for individual wells
- Aggregated total monthly pumping for all wells in a municipality

The village of Lodgepole and city of Sidney were the only two municipalities that reported aggregated monthly pumping values at certain time periods for all their wells. Prior to the calculations, well completion and abandonment dates were reviewed to ensure quantities were calculated for timeframes that pumping occurred, but was not recorded for individual wells.

Conceptually, the process to redistribute aggregated monthly pumping to individual well monthly pumping utilizes monthly recorded pumping information for individual wells to create a distribution pattern. The steps and calculations to distribute this information to individual wells are detailed below. This example assumes recorded monthly pumping per well from 2001 to 2002 to redistribute aggregated pumping in 2003):

1) Calculation of the total monthly pumping for each month with individual well pumping records (T)

   For January 2001: well 1 pumping + well 2 pumping + well 3 pumping… = J_1

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For January 2002: well 1 pumping + well 2 pumping + well 3 pumping… = J_2

$$J_1 + J_2… = T_1$$

2) Calculation of each well's percentage of total monthly pumping per month (D)

well 1 pumping (January 2001) + well 1 pumping (January 2002) … = W_{J1}

$$W_{J1} \div T_1 = D_1$$

3) Calculation of individual well pumping from monthly aggregate pumping (A)

D_1 * monthly aggregate for January 2003 = A_1

Representing pumping in the WWUMM requires the metered pumping information to be distributed to each municipal well monthly, between January 1997 and December 2013. The distribution accounted for each of the municipality's completed wells throughout the modeling timeframe. If a well was constructed during the modeling period, pumping was distributed to that well only after the completion date. All data was analyzed and formatted in a Microsoft Excel workbook: "municipal_final_170417.xlsx".

DISCHARGE DATA

Discharge data was recorded for municipalities in both NRD's. In NPNRD, Bridgeport, Gering, Mitchell, Scottsbluff, and Terrytown had discharge measurements. In SPNRD, Chappell, Kimball, Lodgepole, and Sidney had discharge measurements. SPNRD provided discharge data as part of the NRD's full accounting database, while NPNRD provided discharge data as individual spreadsheets for each municipality. Discharge data was provided as total annual or total monthly discharge data.

Municipalities handle waste water treatment and discharge in diverse ways, with some discharging regularly, others sporadically, or once a year. To ensure a uniform process for calculating net pumping, all discharge data was converted to an annual total for each municipality where data was available. This annual data was redistributed using the same distributions calculated for the pumping data, as described below. This process combines pumping and discharge data to calculate a monthly net pumping term for each well. This also allows for a direct comparison to the calculated baselines for each municipality which is annual net pumping.

NET PUMPING CALCULATIONS

Net pumping was calculated for each municipality separately. To estimate a net pumping value per month per well, the monthly pumping and discharge data were distributed to each well using the following method:

1) Calculation of total for all wells with individual well pumping records per month (T)

well 1 pumping + well 2 pumping + well 3 pumping… = T_1

2) Calculation of each well's portion of total monthly pumping per month (D)

well 1 pumping $\div T_1 = D_1$

3) Calculation of each month's portion of annual pumping (DA)

$$T_1 + T_2 + T_3… = A_1$$
$$T_1 \div A_1 = DA_1$$

4) Calculation of portion of annual discharge to be redistributed with monthly pumping (Q)

discharge * D_1 * $DA_1 = Q_1$

5) Calculation of monthly net pumping (N)

well 1 pumping - $Q_1 = N_1$

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Subsequent references to net pumping reflect this process. For municipalities that do not have discharge records, gross pumping was utilized, and pumping was assumed to be 100% consumptively used.

POPULATION and ANNUAL NET PUMPING ESTIMATES

To estimate municipal pumping values prior to flow meter or pumping records, estimated per capita pumping was utilized. Per capita pumping for each municipality was calculated using annual municipal population data and the available historical pumping volumes. The annual population dataset was created by linear interpolation through the 2000 and 2010 populations, retrieved from the U.S. Census Bureau records. As census data is decadal, only published 2000 and 2010 populations were used. The process for estimating annual per capita pumping included:

- Estimation of annual populations for each municipality from 1997 through 2013.
- Calculation of annual per capita pumping by dividing annual net pumping by annual estimated population.
- Annual per capita pumping was averaged for all years with complete annual pumping datasets.
- Average annual per capita pumping estimates were used to fill data from 1997 to the first full year that net pumping values were available. For example, Big Springs average per capita pumping was utilized from 1997 through 2006.
- These annual per-capita values for each city were then multiplied by the estimated annual population of the city for the same year, providing estimated annual net pumping for years that did not have pumping records (E).

A portion of the municipal pumping records begin mid-year. These records were not included for estimating annual per capita pumping, to prevent any skewing of annual averages.

MONTHLY NET PUMPING

Annual net pumping estimates synthesized using per capita values were converted to monthly pumping values per well, to match the format of historical pumping records and for the creation of the ground water model well file. This conversion was based upon the average monthly distribution and calculated in a comparable manner to step 3 of the NET PUMPING CALCULATIONS section above. The monthly net pumping for all wells in the municipality was summed for each month, with the quotient of this monthly sum and the total sum representing the pumping distribution that was used to redistribute the synthesized annual values. The process included:

1) Calculation of total monthly net pumping for all wells in a municipality (T)
$$well\ 1\ pumping + well\ 2\ pumping + well\ 3\ pumping… = T_1$$
2) Calculation of each month's portion of annual pumping (DA)
$$T_1 + T_2 + T_3… = A$$
$$T_1 \div A = DA_1$$
3) Calculation of synthesized monthly net pumping (S)
$$DA_1 * annual\ net\ pumping\ (E_1) = S_1$$

DISTRIBUTING MONTHLY SYNTHESIZED DATA BASED OFF WELLS PER CITY

The monthly pumping calculation described above (S) defines the estimated total monthly pumping for each municipality. These values were then distributed to the wells that were active

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for each given month. This represents an equal distribution of estimated pumping, with each active well pumping the same amount

NRD records of well completion were reviewed to determine which, if any, wells began pumping during the model period. If a well became active during the period, the previous distribution was adjusted to include the new well. For example, the city of Bayard had a single active well in 1997 which received 100% of the monthly pumping for each month of that year; two addition wells came online in 1998, so each well then received 33% of the estimated monthly pumping. Along with contacting each NRD, well information was retrieved from the Nebraska Well Retrieval site. Some well completion dates fell within the middle of a month, in which case, the completion date was modified to the first day of the nearest month. Since pumping records from 2006 through 2013 for all municipalities, it was assumed that any well abandonments or changes in pumping regime were reflected in the meter data.

FINAL DATASET
A final dataset was created by combining the historical monthly net pumping and synthesized monthly net pumping data. If historical data was available, it was included, if it was not, the synthesized data was used.

ADDITIONAL ASSUMPTIONS
Several assumptions were made during the creation of the municipal pumping dataset that has not already been described. There is a general assumption that pumping always occurred on the first day of the month proceeding for the entire month. It was also assumed that the full historical pumping record provided the most accurate dataset for calculating pumping distributions. Utilizing the full range of available data also allowed for a uniform approach to filling unreported or unavailable data, as the ranges to be filled varied in length and location.

Several municipalities had single months, or ranges of several months, with no reported data during the metered timeframe. These values were filled by averaging that month for the years the month did have pumping (e.g. July 2005 would have been filled with the averages of July 2003, July 2004, July 2006…, etc.).

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Appendix A

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Table 1 – Full-Year of Metered Pumping Information by Municipality

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Bayard								X	X	X	X	X	X	X	X	X	X
Big Springs											X	X	X	X	X	X	X
Bridgeport						X	X	X	X	X	X	X	X	X	X	X	X
Broadwater					X	X	X	X	X	X	X	X	X	X	X	X	X
Bushnell						X	X	X	X	X	X	X	X	X	X	X	X
Chapell											X	X	X	X	X	X	X
Dalton						X	X	X	X	X	X	X	X	X	X	X	X
Dix					X	X	X	X	X	X	X	X	X	X	X	X	X
Gering					X	X	X	X	X	X	X	X	X	X	X	X	X
Gurley						X	X	X	X	X	X	X	X	X	X	X	X
Henry					X	X	X	X	X	X	X	X	X	X	X		
Kimball						X	X	X	X	X	X	X	X	X	X	X	X
Lodgepole						X	X	X	X	X	X	X	X	X	X	X	X
Lyman					X	X	X	X	X	X	X	X	X	X	X		
Minatare					X	X	X	X	X	X	X	X	X	X	X	X	
Mitchell					X	X	X	X	X	X	X	X	X	X	X	X	X
Morrill					X	X	X	X	X	X	X	X	X	X	X		
Oshkosh					X	X	X	X	X	X	X	X	X	X	X	X	X
Potter						X	X	X	X	X	X	X	X	X	X	X	X
Scottsbluff					X	X	X	X	X	X	X	X	X	X	X	X	X
Sidney						X	X	X	X	X	X	X	X	X	X	X	X
Terrytown					X	X	X	X	X	X	X	X	X	X	X	X	X