# Memo

**Adaptive Resources, Inc.**

| | |
|---|---|
| To: | Western Water Use Management Modeling Joint Board |
| From: | Thad Kuntz, P.G., and Joe Reedy |
| Date: | 12/14/2015 |
| Re: | Technical Documentation: Update of Stream Baseflow Calibration Targets |

## INTRODUCTION

To update the Western Water Use Management (WWUM) Modeling ground water model's calibration through April 2014, a comparison of the computed stream baseflow to estimated historical stream baseflow was completed. For more details on the ground water model and the use of stream baseflow target data see the report *Ground Water Flow Model for the Southern Half of the Nebraska Panhandle* (Luckey, 2013) as well as the report *Hydrograph Separation Methods Used to Estimate Groundwater Discharge for Assistance in Calibration of the Western Water Use Model* (Bradley et al., 2013). Targets were updated for the North Platte River (mainstem) and its main tributaries where gage data was available.

## GROUND WATER DEVELOPMENT PERIOD TARGETS: 2014 MODEL UPDATE

The existing ground water development period stream baseflow calibration targets were extended from May 1, 2011, to December 31, 2013. The targets were updated based on the availability of daily historical stream gage data which was provided by Kara Sobieski of Wilson Water Group. Review of available data determined that 17 of 35 targets had either previously unincorporated data, recent data, or both that could be utilized for the updated model calibration. Original mainstem baseflow targets were estimated from historical stream flow data using the pilot point method, while tributary targets may have been estimated by the pilot point method or digital filter (Luckey, 2013; Bradley et al., 2013). The updated targets were estimated using a digital filter to ensure objective and reproducible values that can be easily extended as the ground water model continues to be developed and updated. In this case, baseflow was estimated from daily stream flow data using a one parameter digital filter (Lyne and Hollick, 1979; Nathan and McMahon, 1990; Arnold and Allen, 1999; Arnold et al., 2000), implemented manually for multiple filter passes, and verified through the *Web-based Hydrograph Analysis Tool, or WHAT* (Lim et al., 2005) for select targets.

Following identification of the 17 baseflow targets for the update, information from the Nebraska Department of Natural Resources (NDNR) for the original model calibration was reviewed to determine which anthropogenic impacts were accounted for during baseflow estimation. This data was reviewed and compiled into the file *adjustment_gage_summary_jr_150210.xls*. The relevant daily gage and diversion data were compiled into excel workbooks for each gage. January 1, 2000, to December 31, 2013, was selected as the working range for this update and was isolated from all historical data for each gage and its upstream diversions. The data was then filled to ensure each dataset included all days for that range, with days for which no record existed represented with a blank flow value. Similar processes for calculating final total stream flow for input into the digital filter were used for mainstem and tributary gages.

Total Gage Flow = Gage Flow + Upstream Diversion Flows

Total gage flow was calculated on a daily basis, and missing data was represented with a date followed by a blank flow value. In the case of missing gage data, no value was calculated for total gage flow even if upstream diversion flow data was available. To simplify processing, date values were coupled with a range of values representing days from 1 to 5114, with 1 corresponding to January 1, 2000, and 5114 corresponding to December 31, 2013. This provided a working unique ID used to sort the data for multiple digital filter passes. The final total flow was then filtered to include only dates with a real total flow value, ignoring blank or missing values. The filtered data was copied to a new worksheet for final baseflow estimation.

For selected gages, the filtered total flow values were uploaded to WHAT, and the single parameter digital filter was applied using an alpha parameter of 0.925 (Bradley et al., 2013). The resulting baseflow separated file was processed in Microsoft Excel to be used as a check for the manually estimated values.

In the baseflow estimation worksheet, the single parameter digital filter was applied to the total flow data using an alpha parameter of 0.925 (Bradley et al., 2013). Following this first pass, the unique ID and estimated baseflow values were copied to new columns and reversed. A second pass was made with the digital filter, the results of which were reversed once more to correct the values "in time" before a third pass was made. Using the date values, the average estimated baseflow for each month was determined and converted to cubic feet per day for each digital filter pass.

For tributary gages, the average value for the first pass of the digital filter was used as the final baseflow calibration target. For main stem gages, this average monthly baseflow rate was combined with the similar rate for the main stem gage immediately upstream; providing the final baseflow calibration target for the mainstem gage. This was done in part because streamflow in the model reflects a flow component introduced in the first cell at the western model boundary. The North Platte River basin is also highly developed, complicating baseflow estimation along the mainstem as compared to the various tributaries.

Main Stem Baseflow = Gage Baseflow + Upstream Diversions

The process to update the ground water level calibration targets was conducted utilizing multiple excel workbooks. A working directory was created for each updated gage. Raw gage and diversion data were parsed into the relevant gage directory, in which the data was processed for application of the digital filter. The results were output into the same workbook, and processing for final baseflow estimation was carried out in the excel workbook titled with the relevant gage number. The single parameter digital filter can be applied to streamflow data three times; forward, backward, and forward using the method described above. In general, each successive pass of the digital filter results in baseflow as a smaller percentage of total flow. Phase shift may be a concern when using multiple passes of this type of digital filter; the third pass roughly zeroes the temporal shift that is created by the second, backward pass of the digital filter. Additionally, the alpha parameter utilized by the filter may be adjusted for the conditions and characteristics of individual basins. In general, increasing the alpha parameter results in a decrease in the amplitude of estimated baseflow, especially the leading portion of the baseflow peaks. The same alpha parameter should be utilized for all passes of the digital filter. For the ground water model update, only the first pass of the filter was used, as this was believed to be the same method utilized in the initial model calibration for tributary gages, though all three passes were estimated and the data is available for future calibration updates.

From the 2011 ground water model, *model_1953-2011_130621.gwv*, all stream baseflow calibration targets were exported. The target type was stream flux (node), with stream flux representing surface flow. This file, *model_1953-2011_130621_baseflow_target.csv*, provided the format for the target extension and update. The relevant baseflow calibration targets were compiled into an updated baseflow text file beginning in October 1, 2006 through April 30, 2014; *model_1953-2014_150707_bflow_pass1.csv*. Target name, site coordinates, model coordinates, weight, group, zone, and time data were all checked against the 2011 ground water model for the updated target dataset. This text file was used to create a target shapefile, *model_1953-2014_150707_bflow_pass1.shp*. The original flux (node) targets were deleted from the updated groundwater model. The shapefile was then imported into the ground water model to provide a continuous target range from May 1, 1953, to April 30, 2014.

As all previous ground water model stream baseflow calibration target information is included in the most recent dataset, this dataset supersedes previous efforts and should be consulted for any future ground water stream baseflow calibration information needs along with the relevant documentation (Bradley, et al., 2013, Kuntz and Reedy, 2016, and Luckey, 2013).

**REFERENCES**

.
Arnold, J.G., and Allen, P.M., 1999, Validation of Automated Methods for Estimating Baseflow and Groundwater Recharge From Stream Flow Records: Journal of American Water Resources Association, v. 35, p. 411-424.

Arnold, J.G., Muttiah, R., Srinivasan, R., and Allen, P.M., 2000, Regional Estimation of Baseflow and Groundwater Recharge in the Upper Mississippi River Basin: Journal of Hydrology, v. 227, p. 21-40.

Bradley, J.R., Kuntz, T., and Luckey, R.R., 2013, Hydrograph Separation Methods Used to Estimate Groundwater Discharge for Assistance in Calibration of the Western Water Use Model: Nebraska Department of Natural Resources Report, 14 p.

Kuntz, T.A., and Reedy, J.R., 2016, Western Water Use Management Ground Water Model Update through April 2014, Report to North Platte Natural Resources/South Platte Natural Resources

Lim, K.J., Bernard, E.A., Zhenxu, T., Joongdae, C., Ki-Sung, K.., Muthukrishnan, S., and Tripathy, D., 2005, Automated Web GIS Based Hydrograph Analysis Tool, WHAT: Journal of the American Water Resources Association, v. 41, p. 1407-1416.

Luckey, R.R., 2013, Ground Water Flow Model for the Southern Half of the Nebraska Panhandle: Nebraska Department of Natural Resources/North Platte Natural Resources District/South Platte Natural Resources District Report, 103 p.

Lyne, V.D., and Hollick, M., 1979, Stochastic time-variable rainfall and runoff modeling: Hydrology and Water Resources Symposium, Institution of Engineers Australia, Perth, v. 79, p. 89-93.

Nathan, R.J., and McMahon, T.A., 1990, Evaluation of automated techniques for base flow and recession analyses: Water Resources Research, v. 26, p. 1465-1473.