Phase 6 Model Enhancements
RGDSS Memorandum
Final

To: File
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Subject: **Phase 6 model enhancements**
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The RGDSS Groundwater Model (the Model) is a MODFLOW groundwater model used to simulate the groundwater flow system of the San Luis Valley and the streams that are in connection with the groundwater system. The current version of the Model called model version 6P98 is the latest iteration of the Model. The Model continues to be updated and refined to more accurately represent the complex groundwater flow system. This document describes the enhancements leading to the current version of the Model

This document includes the following sections:

0.0 Disclaimer

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1.0 Acknowledgment

Numerous individual on the Peer Review Team (PRT) have contributed to development of the current model version known as 6P98. Their efforts have been supported by the Colorado Division of Water Resources, the Rio Grande Water Conservation District, other water user groups as well as individual water users.

2.0 Introduction

The RGDSS Groundwater Model (the Model) is a MODFLOW groundwater model used to simulate the groundwater flow system of the San Luis Valley and the streams that are in connection with the groundwater system. The current version of the Model called model version 6P98 is the latest iteration of the Model. The Model continues to be updated and refined to more accurately represent the complex groundwater flow system.

The RGDSS developments are divided into various phases. This document describes the enhancements leading to the current version of the Model.

The initial version of the Model presented in case number 04CW24 was 4P13. This model formed the basis of the Confined Aquifer Rules. By the time this case went to trial in 2005, the current model version was 4P16, which was also presented at trial. This represents the Phase 4 model which had a study period of 1950-2002.

With the formation of Subdistrict No. 1 in 2009, the 5P12 model was used to calculate and prepare response function for Subdistrict No. 1. This represents the Phase 5 model with a study period of 1950-2005.

The response functions were refined in 2012 for the Annual Replacement Plan using an early version of the Phase 6 model known as 6P35. The study period for this version of the model was 1950-2009.

The current Phase 6 model is 6P98, which was used to calculate response functions for Response Areas. The study period for this version of the model was 1950-2010.

The enhancements to the model were made under the direction of the Peer Review Team to better represent the behavior of the groundwater flow system. This document describes the model enhancements performed during Phase 6, and includes enhancements made prior to model version 6P35.

In this memorandum, for consistency between sections, “pumping” is used to describe groundwater withdrawals whether the withdrawal is by a mechanical pump or if the well flows under artesian pressure.

3.0 Phase 6 Refinements

The study period for the 6P98 model is 1950 to 2010. The Monthly Transient model simulations are from 1970 to 2010. The initial heads for the Monthly Transient model are provided by the Initial Period steady state simulation which represents average conditions for the years 1967 to 1969.

3.1 Model Geometry

The model geometry was refined in the south-west corner of the model based on new geophysics information gathered by the USGS. The basin east of San Pedro Mesa was refined to be bounded along the southern edge instead of having a connection to the south. The state line outflow therefore occurs only west of San Pedro Mesa.

Model layers around the Town of San Luis and the Conejos/Rio San Antonio/Los Pinos area were refined to better reflect more recent studies by HRS.

The extent of the model along the Conejos and Saguache Creek valleys in the deeper layers were refined based on a review of the data by HRS. The model domain was refined near the state line around the upper reach of the Rio San Antonio.

The Mesita Fault was extended in the deeper layers underneath Culebra Creek to the San Luis Hills.

3.2 GIS and StateDGI

The StateDGI data processing tool is used to map the GIS data to model cells. Minor changes to StateDGI were required to accommodate new versions of the ArcGIS software. Most of the 6P98 enhancements were to the data, including

- Enhancements were made to the irrigated land coverage for 1998 based on newly available data;
- New irrigated land coverages were created for 2002, 2005, 2009, and 2010;
- Improvements were made to the assignment of well water sources to irrigated parcels based on improved location data;
- Refined mapping of wells to layers were made based on addition data entered into the well database from permits;
- Updated structure locations using GPS measurements;
- Updated GIS coverages of ditch service areas based on interview;
- Reprocessing of native lands classification theme considering enhanced 1998 irrigated land coverage ;
- Addition of cover crop, fall winter wheat, new alfalfa, and bluegrass crop types ;
- Refinement of sprinkler acreage timeline.

3.3 StateCU

StateCU was used to calculate ditch water budgets for the period 1950 to 2010. Metered well pumping were available for 2009 and 2010. Numerous enhancements to the StateCU processing were implemented including:

- The study period was extended through 2010;
- The StateCU code was enhancements to handle metered pumping data and to output detailed summary to the 4WB file for StateFate;
- Metered pumping was incorporated into diversion records;
- The monthly effective precipitation method was changed to the USBR method with the removal of days with ineffective precipitation less than or equal to 0.05 inches;
- Crop characteristic and crop coefficient data:
  - Added new crop types for New Alfalfa and Cover Crop
  - Revised planting dates and frost dates based on peer review
- Refinements to structures included:
  - Aggregated diversion structures were disaggregated and the individual structures were modeled explicitly;
  - Revision to the multistructure dataset based on user supplied data and interviews;
  - Ground water only lands aggregated for Response Areas
  - Reviewed historic diversions within the domain and updated the structure list
  - Revised climate weighting method through a Thiessen polygon approach
  - Updated available water holding capacity values based on revised irrigated lands coverages
- Refinements to diversions included:
  - Wet/Dry/Average pattern filling was refined to utilize one long term stream gage in each Water District
  - Multiple diversion files have been created to better represent complicated systems
- Crop Distribution and Irrigation Practice files
  - Acreage and crop type interpolations were implemented between years based on irrigated lands coverages to incorporate additional imagery/cropping
  - Ditch conveyance efficiencies updated to include information from interviews
  - Ditch conveyance efficiencies were updated to represent the revised structure list and multistructure list

3.4 M&I Pumping and Returns

The M&I pumping and return data were substantially revised. The tools to update these time series were updated and consolidated. In particular

- Lists of wells included were based on decreed and permitted uses;
- Historic diversion estimates were revised based on newly available data;
- Return flow locations were revised based on interviews;
- Processing of Closed Basin Project volumes were streamlined;
- Returns from special cases such as fish farms to streams were refined.

3.5 Small Flowing Wells

The small flowing well dataset was refined based on updated location and yield information. Data were reviewed to ensure that wells in the domain were included in one of the model datasets.

3.6 Rim Recharge

The spatial extent of the rim recharge areas were refined based on physical features up to a maximum of 2 miles from the model boundary. The mapping of the drainages to rim recharge areas were refined and the gages used to estimate rim recharge volumes were reviewed and refined. New rim inflow volumes were calculated based on refined data.

3.7 StateFate

The StateFate data processing tool was created to update to streamline the transfer of data from StateCU to StatePP. The ***.Xpp** file format was defined to represent the ditch water budgets in a format suitable for StatePP.

The purpose of StateFate is to distinguish how, for example, a quantity such as spray loss is treated differently in StateCU and StatePP. In StateCU, spray loss is lumped in with groundwater recharge as not satisfying the crop consumptive use. In StatePP, spray loss is lumped in with crop consumptive use as water not returning to the groundwater system.

More detail is provided in the *StateFate* documentation dated November 2015.

3.8 StatePP

The StatePP program builds the MODFLOW input files. The enhancements to this program for version 6P98 include

- Treating groundwater recharge of surface water as a separate term and distributing this recharge proportional to the well pumping distribution
- Allowing returns from surface and groundwater to be saved as separate recharge terms

3.9 Streams

The stream package was enhanced

- Major and Garner Creeks was moved from the stream package to Rim Inflow;
- The Saguache Town Drain was added to the stream network;
- The San Luis Valley Drainage District, also called the La Jara Drain, was added to the stream network;
- The routing of Cotton Creek was updated to reflect the current stream channel and connected to San Luis Creek;
- The Rio Grande Drain to Prairie Ditch routing was added;
- New stream surveys for the Saguache Creek, San Luis Creek, the Norton Drain and the La Jara Drain were incorporated;
- The Rock Creek/Waverly Drain was connected to the Rio Grande;
- The connection from the Bowen Drain to the Rio Grande was removed;
- Updates to diversion and return locations and quantities.

3.10 ET and Subirrigation

The ET areas were updated to the new ET coverages. The ET curves for native species were modified to reflect Dr. Cooper's updated curves. The monthly distribution for native vegetation was refined to include ETg during the winter months.

The subirrigation curves with depth were updated based on information from the Peer Review Team. The subirrigation extinction curve was updated to use a truncated maximum value that matches the StateCU maximum potential subirrigation value. Previously, the extinction curve was always a fraction of the maximum potential subirrigation.

3.11 Boundary flows

The boundary inflows in the area around the Town of San Luis were updated based on the new understanding of the model geometry in this area. HRS provided new estimates of the inflows in this area.

The distribution of subsurface inflow along the western boundary of the Model was updated to reflect the refinements to the model geometry, and a spatial distribution provided by HRS.

The state line flow was updated to reflect the new model geometry. The state line general head boundaries were adjusted as part of the model calibration.

3.12 Calibration Procedures

The refinements leading to the calibration of 6P98 involved

- All calibration runs were performed using full Monthly Transient simulations;
- Merged well and recharge files were created to speed up Monthly Transient runs;
- Targets were added to minimize flooded cells, i.e. heads above the ground surface;
- Targets were added to minimize dry cells, i.e. heads below the bottom of a cell;
- Additional well targets were generated using water levels from well permits when no observation wells were nearby;
- HRS performed a review of the well permit data to eliminate inappropriate observations;
- Water level observations from the USGS, USBR, Divide Studies, RGWCD well network and several local studies were updated and incorporated as targets;
- Baseflow estimates to major streams were updated and incorporated as targets;
- The baseflow gain estimate procedures were refined;
- The baseflow gain reaches and time periods were refined;
- The unmet diversion targets were added based on water commissioner review;
- The sweeping diversion targets were added based on water commissioner review;
- Target weights were rebalanced to reflect observation groups;
- Instead of using property zones, aquifer properties within a property zone were constrained through regularization;
- Streambed conductances were added to the parameter set;
- Instead of estimating Kv directly, the Kh:Kv ratio is estimated instead;
- HRS established reasonable values for the Kh:Kv range;
- The length and width of the Manassa Fault was refined based on HRS mapping;
- The aquifer property transition at the western edge of the Manassa Fault was changed to be abrupt instead of gradually transitioning to the Conejos properties;
- New outputs, such as the percentage of the time that the drain is flowing, were generated for review by parties with local knowledge.

3.13 Model Application

For 6P98 the administrative reaches were refined based on PRT and DWR input. The model was applied to evaluate impacts from Response Areas that cover hydrogeologically similar areas.

The Model was used to calculate responses for each of the Response Areas. These

modeled responses were calibrated to the historical impacts calculated by the Model. The resulting Response Functions are recommended for use in administration.

4.0 Comments and Concerns.

As the RGDSS Groundwater Model has matured, the pre-processing steps have been streamlined which has made model updates easier. However, further improvements to this process need to be made to allow the study period to be updated more frequently. The trade-off is to maintain flexibility to accommodate changed circumstances, and automating many of the steps involved.

We anticipate that further refinements to the Model and the data processing will continue to be necessary for several more years.

5.0 References

RGDSS Phase 5 Ground Water Model Enhancements, Ray R. Bennett, June 22, 2009.

RGDSS Phase 6 Ground Water Model Enhancements, James R. Heath May 1, 2012.

RGDSS Hydrogeology Review: Southeast Model Boundary Grid, Layering, and